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**JOINT ADVANCED WARFIGHTING SCHOOL**



**INTEGRATING THE UNMANNED AIRCRAFT SYSTEM INTO THE  
NATIONAL AIRSPACE SYSTEM**

by

**Cory A. Mendenhall**

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**A paper submitted to the Faculty of the Joint Advanced Warfighting School in partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning and Strategy. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense.**

**This paper is entirely my own work except as documented in footnotes. (or appropriate statement per the Academic Integrity Policy)**

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## **ABSTRACT**

In the last 10 years, the unmanned aircraft system (UAS) has captured the public's imagination and fascination with their ability to provide instantaneous video feeds of military and covert CIA operations in far away places like Afghanistan and Iraq.

The rapid proliferation of the UAS and the eventual redeployment of current systems deployed to Afghanistan and Iraq will require the Federal Aviation Administration (FAA) to provide unrestricted unmanned aircraft access within the National Airspace System (NAS). The Department of Defense (DoD) requires routine access to the NAS to execute directed missions, meet training requirements, and perform necessary testing to meet the Joint Force Commander's (JFC's) established mission priorities. Over the past several years, the DoD has been able to execute a small portion of UAS flights in the NAS but current rules and regulation do not facilitate seamless integration with manned aircraft.

The purpose of this study is to show that although the DoD and the FAA recognize the importance of integrating manned and unmanned aircraft within the NAS, there are many challenges and gaps that must be bridged to facilitate successful integration. The most important challenge to overcome when integrating manned and unmanned aircraft into the same airspace is safety.

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## **ABBREVIATIONS**

ABSAA	Air-Based Sense and Avoid
AC	Advisory Circular
AGL	Above Ground Level
AI	Artificial Intelligence
AIM	Aeronautical Information Manual
AMS	Acquisition Management System
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATS	Air Traffic System
BAMS	Broad Area Maritime Surveillance
CDA	Commercial Derivative Aircraft
CFA	Controlled Firing Area
CFR	Code of Federal Regulation
COA	Certificate of Authorization
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FCC	Federal Communications Commission
FSS	Flight Service Station
DHS	Department of Homeland Security
DoC	Department of Commerce
DoD	Department of Defense

DoT	Department of Transportation
EXCOM	Executive Command
FL	Flight Level
FY	Fiscal Year
GAO	Government Accountability Office
GBSAA	Ground-Based Sense and Avoid
GCS	Ground Control Station
GPS	Global Positioning System
HALE	High Altitude Long Endurance
IFR	Instrument Flight Rules
ISR	Intelligence, Surveillance, and Reconnaissance
JFC	Joint Force Commander
JP	Joint Publication
JUAS CoE	Joint Unmanned System Center of Excellence
LOS	Line of Sight
LSA	Light Sport Aircraft
MALE	Medium Altitude Long Endurance
MOA	Memorandum of Agreement
MPH	Miles per Hour
MSL	Mean Sea Level
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NextGen	Next Generation Air Transportation System

NM	Nautical Mile
PBN	Performance-Based Navigation
QDR	Quadrennial Defense Review
RC	Radio Control
SAA	Sense and Avoid
SAC	Strategic Air Command
SOF	Safety of Flight
STC	Supplemental Type Certificate
SUA	Special Use Airspace
TAC	Tactical Air Command
TC	Type Certificate
TCAS	Traffic Collision Avoidance System
TLS	Target Level Safety
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight Rules

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## CHAPTER 1

### INTRODUCTION

In the last 10 years, the unmanned aircraft system (UAS) has captured the public's imagination and fascination with their ability to provide instantaneous video feeds of military and covert CIA operations in far away places like Afghanistan and Iraq. The UAS is a complex system that consists of a pilotless aircraft and a ground control system. The pilotless aircraft is often referred to as an unmanned aircraft (UA) that can be controlled by the ground control system or be preprogrammed prior to launch for flight. The ground control system provides a radio control link to the UA, with the capability of remotely controlling the aircraft from miles away.

The UAS not only provides countless hours of "video game-like" imaginary, it enables commanders to observe and sometimes control operations worldwide. The UAS has been extremely effective delivering accurate pinpoint munitions, like the Hellfire missile, to the back steps of our enemy worldwide.

As we continue sustained combat operations in support of the War on Terror, there has been a significant evolution in the current and planned future use of UAS. The Department of Defense (DoD) plans to invest billions of dollars in the development and procurement of UAS. Just last year, the DoD requested \$6.1 billion to expand the current capabilities of the UAS and expects an additional \$25 billion will be needed for further expansion.<sup>1</sup> Since 2002, the DoD has gone from 50 UAS to in excess of 6,800 UAS,

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<sup>1</sup> Michael Sullivan. *DoD Could Achieve Greater Commonality and Efficiencies among its Unmanned Aircraft Systems*, GAO-10-508T. (Washington, DC: Government Accounting Office, March 23, 2010). 4.

providing different capabilities and opportunities for the future in unmanned flight.<sup>2</sup> In response to increasing budgets and expanding UAS fleets, the DoD and all military service components (Army, Navy, and Air Force) have developed comprehensive UAS strategies that address the development, organization and employment across the full spectrum of military operations. Once a system that was designed for use as a primary intelligence, surveillance, and reconnaissance (ISR) platform, the UAS has graduated to more advance missions to include weapons targeting. Future uses for cargo lift and medical evacuations in combat are also being evaluated by all military components. These adaptations can be attributed as the direct result in the growth of capabilities in our current UAS force.

The rapid proliferation of the UAS and the eventual redeployment of current systems deployed to Afghanistan and Iraq requires the FAA to provide unrestricted unmanned aircraft access within the NAS. While growth continues over the next 25 years, the ability to integrate UAS into the National Airspace System (NAS) in support of the Joint Force Commander (JFC) has not kept pace. The DoD requires routine access to the NAS to execute directed missions, meet training requirements, and perform necessary testing to meet the JFC's established mission priorities. Over the past several years, the DoD has been able to execute a small portion of UAS flights in the NAS but current rules and regulation do not facilitate seamless integration with manned aircraft.

The FAA has been slow to respond to the needs of the DoD. For UAS to operate within the NAS they must do so in accordance with FAA regulations designed for manned aircraft flights and under a restrictive DoD-FAA memorandum of agreement

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<sup>2</sup> *Unmanned Aircraft Systems: Comprehensive Planning and a Results-Oriented Training Strategy are needed to Support Growing Inventories*, GAO-10-331. (Washington, DC: Government Accountability Office, March 26, 2010). 1.

(MOA) signed in 2007. Further analysis will identify gaps within FAA regulations and challenges the DoD must meet to bridge these gaps if successful integration is to occur. Ultimately, the desired end state for the DoD is routine NAS access equal to manned aircraft for all UAS operational, training and support missions.

### **Purpose**

The purpose of this study is to show that although the DoD and the FAA recognize the importance of integrating manned and unmanned aircraft within the NAS, there are many challenges and gaps that must be bridged to facilitate successful integration. The most important challenge to overcome when integrating manned and unmanned aircraft into the same airspace is safety.

### **Thesis Statement**

The importance of unmanned aircraft, particularly in national defense, has increased significantly, but the safe integration of manned and unmanned flight is a challenge facing bureaucratic inertia and in need of our government's emphasis on resolution.

This paper will explore the current regulatory challenges and gaps that exist with successfully integrating UAS within the NAS and discuss possible solutions for consideration. First, this study will begin with the historical background of the FAA, the evolution of the UAS, current capabilities, and its future. Next, this study will define the operational environment that both manned and unmanned systems operate within. Third, this study will identify current challenges and gaps with safety standards, FAA regulations, technology, and operations that prevent seamless manned and UA integration



within the NAS. Finally, this study will make recommendations based on the author's experience and research, to successfully integrate UAS within the NAS and then conclude.

### **Limitations**

The author placed three limitations on this research to limit overall length and ensure the study remained unclassified. First, this research solely examines the integration of manned and unmanned aircraft systems within the United States' NAS and does not consider challenges worldwide. Although other countries are faced with similar challenges with integrating UA within their own airspace system, this analysis will focus on regulations and requirements that are unique only to the United States NAS.

Second, this research examines only U.S. DoD access to the NAS and does not consider multinational or civilian access. Although civilian UA access to the NAS is inevitable, the DoD access is currently more critical based on sheer numbers of systems.

Finally, artillery projectiles, cruise missiles and other types of ballistic vehicles were not considered in this research. Although, during early stages of development many of these systems were referred to as unmanned aircraft, joint doctrine does not recognize these systems as UA.<sup>3</sup>

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<sup>3</sup> U.S. Joint Chiefs of Staff. *DoD Dictionary of Military and Associated Terms*, Joint Publication 1-02 (Washington, DC: Joint Chiefs of Staff, November 8, 2010), 563.

## **CHAPTER 2**

### **BACKGROUND**

#### **The Federal Aviation Administration (FAA)**

The FAA oversees the safety of all civilian aviation within our National Airspace System (NAS). Additionally, the FAA is responsible for the issuance and enforcement of regulations and standards related to the manufacture, operations, certification and maintenance of aircraft within the United States. The agency operates an entire network of systems that ensures safe air and ground related services. Oversight of airfield control towers, air traffic control centers, and flight service stations (FSS) are all required. Additionally, the FAA develops air traffic rules, allocates airspace usage for civilian and military organizations, and “provides for the security control of air traffic to meet national defense requirements.”<sup>1</sup>

The history and need for the establishment of the FAA can be traced back to December 17<sup>th</sup>, 1903 when Orville Wright made the first sustained, powered flight in a plane that he built with his brother, Wilbur.<sup>2</sup> Their historical flight eventually led to a revolution in modern travel for both military and civilian applications.

Following World War I, technical developments moved slowly and early aviation remained a dangerous mode of transportation. Pilots flew 200 to 500 feet above the ground using roads as their primary means of navigation. Rules for flying at night or

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<sup>1</sup> Department of Transportation. “U.S. Department of Transportation/DoT Organizations,” May 2009. <http://www.dot.gov/summary.htm> (accessed February 15, 2011).

<sup>2</sup> Federal Aviation Administration (FAA). “A Brief History of the FAA,” 1. [http://www.faa.gov/about/history/brief\\_history](http://www.faa.gov/about/history/brief_history) (accessed November 30, 2010).

during low visibility were non-existent and fatal accidents were routine.<sup>3</sup>

In response to pressure for federal action to improve and maintain safety standards in aviation operations, the Air Commerce Act was passed in 1926. This act charged the Secretary of Commerce with establishing a Aeronautics Branch to assume primary responsibility for issuing and enforcing all air related rules, licensing pilots, certifying aircraft, establishing airways and operating and maintaining air navigation aids.<sup>4</sup>

The birth of the Federal Aviation Agency (later changed to Federal Aviation Administration) on August 23, 1956, followed a catastrophic accident that killed 128 occupants in Arizona. Two airline planes collided over the Grand Canyon while flying under visual flight rules in non-congested airspace. The accident reminded aviation officials that although U.S. traffic services had doubled since World War II, little had been done to mitigate risk of midair collisions.<sup>5</sup> Ultimately, the Federal Aviation Agency (FAA) was charged with the responsibility of ensuring the safety of civil aviation.

During the 1960s, the FAA's responsibilities increased due to improvements in aviation technology and environmental concerns. The FAA felt a need to modernize the NAS air traffic control system to ensure airport and airspace safety. Airport traffic control towers increased by 112 percent while the FAA employed the first use of radar, radio communications, and air traffic operators to help and monitor aircraft movements.<sup>6</sup>

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<sup>3</sup> Federal Aviation Administration (FAA). "A Brief History of the FAA," 1.

<sup>4</sup> Ibid., 2.

<sup>5</sup> Ibid., 3.

<sup>6</sup> Ibid.

Over the next 54 years, the FAA continued to expand air traffic control systems and establish procedures to keep pace with advancements in the aviation. Many of these systems are still in use today. The FAA continues to provide oversight of the safest, most reliable and efficient air transportation systems in the world.<sup>7</sup>

### **Unmanned Aircraft System (UAS)**

Just over sixty years ago, General Henry H. “Hap” Arnold had a vision of the future of manned and unmanned flight and said:

We have just won a war with a lot of heroes flying around in planes. The next war may be fought with airplanes with no men in them at all. It certainly will be fought with planes so far superior to those we have now that there will be no basis for comparison. Take everything you’ve learned about aviation in war and throw it out of the window and let’s go to work on tomorrow’s aviation. It will be different from anything the world has ever seen.<sup>8</sup>

### **UAS Defined**

Until recently, an unmanned aircraft was referred to as an Unmanned Aerial Vehicle or UAV. In 2005, the DoD recognized the need to drop the acronym UAV and broaden the definition to include two terms when referring to unmanned aircraft: an unmanned aircraft (UA) and an unmanned aircraft system (UAS). The UA is referred to as a pilotless aircraft and can be either a fixed-wing aircraft or a rotary-winged aircraft, like a helicopter. The UAS is comprised of two main components: the unmanned aircraft and the ground control system. The ground control system is comprised of several integrated components to include: avionics, fuel, navigation, communications, logistics,

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<sup>7</sup> Federal Aviation Administration (FAA). “A Brief History of the FAA,” 5.

<sup>8</sup> Jay M. Shafritz, *Words on War: Military Quotations from Ancient Times to Present* (New York: Prentice Hall, 1990), 104.

and a human operator. The ground control system provides a radio link to the unmanned aircraft enabling control from great distances. This change in terminology provides clarity and reflects the complexity of the systems required to fly an unmanned aircraft. Additionally, the plural acronym is the same as the singular, UAS.

When comparing DoD and the FAA's definition of UAS there are differences. The Department of Defense (DoD) defines unmanned aircraft (UA) as an aircraft or balloon that does not carry a human operator and is capable of flight under remote control or autonomous programming.<sup>9</sup> Unmanned aircraft systems (UAS) are defined as the system whose components include the necessary equipment, network, and personnel to control an unmanned aircraft.<sup>10</sup> Ballistic or semi-ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles. The FAA defines the UAS as a device used or intended to be used for flight in the air that has no onboard pilot. This would include all types of airplanes, helicopters, airships, and translational lift aircraft.<sup>11</sup>

The FAA's definition of the UAS is simplistic and doesn't fully recognize the complexity of the entire system. In Chapter 4, Analysis and Discussion, the author will explore in greater detail some of the FAA regulatory gaps or non-existent regulations needed to ensure safe integration of UAS within the NAS.

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<sup>9</sup> U.S. Joint Chiefs of Staff. *DoD Dictionary of Military and Associated Terms*, Joint Publication 1-02 (Washington, DC: Joint Chiefs of Staff, November 8, 2010), 388.

<sup>10</sup> *Ibid.*, 388.

<sup>11</sup> Aviation Safety Unmanned Aircraft Program Office (UAPO), *Interim Operational Approval Guidance, Unmanned Aircraft Systems Operations in the U.S. National Airspace System* (Washington: Federal Aviation Administration, 2008), 4.

## Historical Evolution of UAS

### Early Unmanned Flight

The first reference to the military application of unmanned flight was in the second century BC when Han Hsin, an ancient Chinese general, used kites to triangulate the distance for a tunnel his army was digging under a besieged city's walls.<sup>12</sup> Eventually, balloons became one of the primary means for waging war and in 1849; the Austrians attacked the Italian city of Venice with unmanned balloons carrying explosives. Although their effect was limited due to changing wind patterns, the concept would spark the imagination of future pioneers in aviation. Once fixed winged aircraft were invented, the design and vision to fly them unmanned would not be far behind.<sup>13</sup>

Eventually in 1793, the concept of aerial delivery through the use of balloons made its way to America and by the beginning of the Civil War, the Union Army had their own balloon air force called the "aeronaut corps."<sup>14</sup> About mid-Civil War, in 1863, the first patent was awarded for an unmanned aerial bomber using a hot air balloon. Charles Perley of New York City designed a timing mechanism mounted to the bottom of a basket attached to hot-air balloon. A bomb was placed in the basket over the closed opening. When the balloon drifted over its target, the timing mechanism would release a hammer that would eject a hinge pin, causing the door on the bottom of the basket to open. Simultaneously, the ejection pin would ignite the bomb's fuse and the bomb would

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<sup>12</sup> Clive Hart, *Kites: an Historical Survey* (Mount Vernon, NY: P.P. Appel, 1892), 25.

<sup>13</sup> Brett Holman, "The First Air Bomb: Venice, 15 July 1849." (Air-minded, Airpower and British Society, August 2009). <http://air-minded.org/2009/08/22/the-first-air-bomb-venice-15-july-1849> (accessed February 15, 2011).

<sup>14</sup> Charles Evans, *The War of the Aeronauts – A History of Ballooning During the Civil War* (Stackpole Books, Mechanicsburg, PA, 2002).

fall to the target. Timing and wind speeds had to be calculated precisely. Unfortunately, the hot air balloon bomber was never very successful.<sup>15</sup>

In 1884, a Serbian named Nikola Tesla, migrated to the United States with his idea of remotely controlling objects without any controls attached. Tesla demonstrated the ability to remotely control objects wirelessly with the use of a small boat commanded by sending frequencies through radio transmissions or radio waves. In 1915, twelve years following the Wright Brothers first piloted flight, Tesla would publish his dissertation describing an “armed, pilotless aircraft designed to defend the United States.”<sup>16</sup> This was the first genesis for unmanned flight.

December 17<sup>th</sup>, 1903 two brothers name Orville and Wilber Wright conducted the first piloted flight that paved the way for technological innovation for manned flight. While the United States funneled most of their resources into the development of manned flight, unmanned flight would struggle for relevance for the next 100 years.

In 1918, 15 years after the Wright brothers flight, the Royal Army attempted the first radio-controlled flight; resulting in a crash. Less than one year later, on March 6, 1918, a modified Curtiss Speed Scout called the “Aerial Torpedo” made the world’s first successful flight by an unmanned aircraft at Long Island, N.Y. The torpedo was launched in the air by catapult and flew over 1,000 yards before it was recovered and launched again.<sup>17</sup>

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<sup>15</sup> NOVA, “Spies that Fly: A Timeline of UAVs,” November 2002.

<sup>16</sup> U.S. Army *Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army* (Fort Rucker, AL: US Army Unmanned Aircraft Systems Center of Excellence, 2010), 4.

<sup>17</sup> Laurence Newcome, *Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles*, (American Institute of Aeronautics and Astronautics, 2004).

## World War I (WWI)

The use and further development of hot air balloons continued through WWI with limited success. In 1916, Elmer Sperry made the Hewitt-Sperry Automatic Airplane, also known as the “flying bomb”, bridging the gap between manned and unmanned aerial flight. His remote controlled airplane used gyroscopes to achieve wireless flight that eventually led the U.S. Army to commission a project that would result in the building of a new type of unmanned aerial vehicle called the Kettering Bug.<sup>18</sup>

The Kettering Bug was a joint effort between Orville Wright and Elmer Sperry. The airplane was a gasoline fueled propeller biplane, which had the capability to fly on a preset course for over 50 miles.<sup>19</sup> Sperry provided the guidance system, comprised of a gyroscope with altimeter and barometer. Although the Kettering Bug was very successful, WWI would end before any significant testing could be accomplished and eventual budget cuts would terminate the program.

## World War II (WWII)

Following WW I, unmanned aerial system development was not a priority and took a back seat to manned systems. Due to lack of funding and competing demand for manned aircraft, almost all Unmanned Aerial Vehicle (UAV) research was cancelled.<sup>20</sup> In 1935, American movie star, Reginald Denny, produced a family of unmanned target drones as aerial targets for anti-aircraft guns and other armed aircraft. Denny’s target

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<sup>18</sup> Lee Pearson, “Developing the Flying Bomb,” (Naval History and Heritage Command, 2008), 2. <http://www.history.navy.mil/download/ww1-10.pdf> (accessed January 15, 2011).

<sup>19</sup> The Internet Encyclopedia of Science, “Kettering Bug.” [www.daviddarling.info/encyclopedia/K/Kettering\\_Bug.html](http://www.daviddarling.info/encyclopedia/K/Kettering_Bug.html) (accessed January 12, 2011).

<sup>20</sup> Jay Womack and Arthur Steckowski, *Review of Past and Current Trails and Uses of Unmanned Vehicles* (Ft. Belvoir: Defense Technical Information Center, 1988), 2-2.



drones were very successful and the Army Air Corps and Navy purchased over 1,000 of his unmanned vehicles for target practice.<sup>21</sup>

After the U.S. entered WW II, U.S. Army Air Corps and Navy use of UAVs was limited. Under the Project Aphrodite program, radio-controlled B-17 and B-24 bombers, nearing their life expectancy for service, were packed with over 25,000 pounds of explosives and the controls were wired for remote pilotage. The intent of the project was to launch the aircraft with a pilot and technician at the controls. Once airborne, the crew would bail out and the unmanned aircraft would continue on, controlled by a trailing escort aircraft, to the target. Ultimately, the program would fail because of the ineffective precision guidance system and vulnerability to German anti-aircraft defenses.<sup>22</sup>

### Korea to the Persian Gulf

Following WW II, unmanned aerial system development once again was not the priority for the DoD. Modified B-29 bombers were used to launch guided bombs against North Korean targets with minimal success due to poor guidance systems. However, in 1951, the AQM-34L Teledyne Ryan Firebee, was introduced as the world's first jet powered target drone. The Firebee was air-launched and controlled by a DC-130 aircraft. While in flight, the Firebee would conduct low-level photo missions over Southeast Asia and Northern Vietnam. Following mission completion, the Firebee was controlled to a safe location, and then deploy its parachute and land safely on the ground, waiting for air

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<sup>21</sup> Bill Yenne, *Attack of the Drones: A History of Unmanned Aerial Combat* (St. Paul, MN: Zenith Press, 2004), 15.

<sup>22</sup> Ibid., 20.

or ground.<sup>23</sup>

Despite encouraging progress with unmanned flight following the Korean War, competing requirements for acquisition of the SR-71 aircraft and development of satellite technology put unmanned flight far down the priority for funding.<sup>24</sup> Then in 1960, a U-2 reconnaissance airplane piloted by Major Frances Powers was shot down over the Soviet Union while on a mission. Following the shoot down, political pressure and renewed interest in unmanned aircraft by the Air Force resulted in the development of a reconnaissance version of the Firebee target drone named the Lightning Bug. The Lightning Bug flew over 3,435 sorties during the Vietnam War conducting photographic reconnaissance. The Lightning Bug became a milestone in UAV flight and development.<sup>25</sup>

Following the Vietnam War, unmanned aircraft development saw rapid growth until 1976. Due to budget constraints, the U.S. Air Force restructured command responsibilities for unmanned aerial systems. Tactical Air Command (TAC) received overall responsibility for UAV development from Strategic Air Command (SAC). Under TAC, the UAV program deteriorated because of competition for funding with TAC's manned combat aircraft fleet.<sup>26</sup>

Due to lack of funding in 1979, the remaining 60 UAVs in the U.S Air Force inventory were deactivated and put into storage. The following 10 years, from 1979 to 1989, there were no major or significant UAV technological advancements in the United

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<sup>23</sup> M.J. Armitage, *Unmanned Aircraft* (Washington: Brassey's Defense Publishers, 1988), 65-86.

<sup>24</sup> Dana A. Longino, *Role of Unmanned Aerial Vehicles in Future Conflict* (Air University Press, 1994), 2.

<sup>25</sup> Yenne, 25-28.

<sup>26</sup> William Wagner and William P. Sloan. *Fireflies and other UAVs* (Earl Shilton, Leicester: Midland Publishing Ltd., 1992), 108-110.

States.<sup>27</sup>

In Fiscal Year 1988, in an effort to reduce duplication, Congress eliminated separate programs for remotely piloted vehicles within each military service and established the UAV Joint Project Office. In response to Congress' direction, the UAV Joint Project Office developed the first UAV plan called the "Unmanned Aerial Vehicle Master Plan." The master plan's overall goal was to maximize joint development and procurement between the services, providing systems to the field, while reducing overall costs.<sup>28</sup>

Operation Desert Storm marked the first operational employment of UAVs for the U.S. military. UAVs played a significant role in providing near real-time information flying over 330 sorties and 1,000 hours between the Army, Navy and Air Force. The Navy had purchased two RQ-21 Pioneer UAV systems while the other services quickly followed suit (Army purchased one system and the Marines purchased three systems).<sup>29</sup> The purpose of the Pioneer UAV was to provide as an inexpensive, over-the-horizon targeting, reconnaissance, and battle damage assessment (BDA) alternative to manned aircraft.

Many UAV lessons were learned during Desert Storm. Airspace integration between unmanned and manned aircraft proved to be challenging but solvable. The capabilities and performance of the Pioneer UAV provided opportunities in further UAV research and development that ultimately led to the development of the U.S. Air Force

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<sup>27</sup> Yenne, 53-56.

<sup>28</sup> Richard L. Mosier, *Joint Unmanned Aerial Vehicle Program Master Plan 1988* (Washington: Department of Defense, 1988), 1-4. <http://handle/dtic.mil/100.2/ADA/197751> (accessed December 14, 2010)

<sup>29</sup> Longino, 7-9.

Predator.<sup>30</sup>

In 1995, the Air Force stood up the first UAV squadron and received the Predator UAV in 1996. The Predator was first used in Bosnia in 1995 and became more commonly known during Operation Allied Force in Kosovo in 1999.<sup>31</sup> Since Kosovo, the Predator received several upgrades to include the ability to launch on board weapons during Operation Enduring Freedom (OEF) in Afghanistan and Operation Iraqi Freedom (OIF) in Iraq. The military effectiveness of UAVs in Kosovo, Afghanistan and Iraq opened the eyes to both military and civilian onlookers. The many advantages and disadvantages of unmanned aircraft now made national headlines as UAS executed missions, once reserved for manned aircraft, with precision.

### **Current UAS**

Today's UAS encompass a wide range of different sizes and options that allow the user to obtain greater carrying capacity, greater airspeeds, and operate at higher altitudes. The smallest operational UAS used by the military is RQ-11B Raven. This four-pound UAS can fly for up to one hour before it needs refueling and cruise at speed greater than 60 knots up to 1000 feet above the ground.<sup>32</sup> The largest military UAS is the Global Hawk, weighing 25,600 pounds with a top speed of 400 knots. The Global Hawk can fly for over 30 hours at altitudes up to 65,000 feet above the earth's surface.<sup>33</sup>

In the National Defense Authorization Act for FY2001 Congress stated, "Within

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<sup>30</sup> Elizabeth Bone and Christopher C. Bolcom, *Unmanned Aerial Vehicles Background and Issues for Congress* (Washington, D.C.: Congressional Research Service, Library of Congress; 2003), 2. <http://www.fas.org/irp/crs/RL31872.pdf> (accessed December 15, 2010).

<sup>31</sup> *Ibid.*, 22.

<sup>32</sup> *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army*, 73.

<sup>33</sup> U.S. Department of Defense, *FY2009-2034 Unmanned Systems Integrated Roadmap*, (Washington: GPO, 2010), 73.

ten years, one-third of U.S. military operational deep strike aircraft will be unmanned.”<sup>34</sup> Since then, UAS have experienced a rapid explosion in growth and have proved invaluable to the Joint Force Commander (JFC) in executing a full range of operational requirements.<sup>35</sup> UAS provide extremely advanced intelligence, surveillance and reconnaissance (ISR) capability and, if necessary, provide pinpoint weapons delivery against enemy targets. All military services operate a number of different UAS. Some range in size from a small backpack model, like the Raven, to larger runway launched models, like the Global Hawk.

Prior to 2003, when the Army had a handful of UAS in their inventory, it took 13 years to complete 100,000 hours of flight time. Since Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), the Army has flown another 900,000 hours. Today, UAS operations in support of OEF and OIF average just over 25,000 hours a month.<sup>36</sup>

The Army’s UAS fleet includes the Raven UAS, the medium-altitude RQ-7 Shadow, and the MQ-5 Hunter. Additional systems that are currently being tested by soldiers in the field are the Extended Range/Multi-Purpose MQ-1 and the hover-and-stare Micro Air Vehicle (gMAV). The Army now operates 87 Shadow UAS systems, 6 Hunter systems, 9 ER/MP variants, 1,300 Raven systems and 16 gMAV systems.<sup>37</sup> Typically, the Army flies their UAS at altitudes below 18,000 feet mean sea level (MSL) while the Air Force maintains the airspace above 18,000 MSL.

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<sup>34</sup> Public Law 106-39, *National Defense Authorization Fiscal Year 2001*, (October, 2000), Sec. 220 (a). <http://www.DoD.gov/DoDgc/olc/docs/2001NDAA.pdf> (accessed January 15, 2011).

<sup>35</sup> U.S. Department of Defense, *FY2009-2034 Unmanned Systems Integrated Roadmap*, 2.

<sup>36</sup> U.S. Army, “Army Unmanned Aerial Systems Hits One Million Flight Hour Milestone,” (*Stand-To*, 25 May 2010). <http://www.army.mil/standto/archive/2010/05/25/> (accessed January 15, 2011).

<sup>37</sup> *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army*, 73-81.

The U.S. Air Force uses extended range high altitude UAS, like the MQ-9 Reaper (formerly known as the Predator) that flies at altitudes up to 60,000 feet MSL and the MQ-4 Global Hawk that operates above 60,000 feet MSL for almost two days. Since the end of January 2011, the Predator has flown over 800,000 hours of total flight time since its first use in Bosnia in 1995 and the Global Hawk has flown over 100,000.<sup>38</sup>

During a speech at the Army Aviation Association of America Conference in April 2010, Army Vice Chief of Staff General Peter Chiarelli said, "There have been many technologies introduced during these 8 1/2 years of war. However, I don't think any has made a greater impact than UAS. It's always important when you have a game changer like this, that you step back, take some time to think about it, and lay out your future."<sup>39</sup>

### **The Future of UAS**

The UAS is considered a key component of U.S. defense transformation and an integral part of U.S. military doctrine. According to a recent market report from Market Research Media, the U.S. military UAS market is projected to grow at a combined annual growth rate of 10% between 2010 and 2015. Additionally, The report finds that the U.S. military UAS market will generate \$62 billion in revenues over the period 2010 – 2015.<sup>40</sup>

In response to the UAS's predicted expansion in the future, the DoD developed and published the *FY2009-2034 Unmanned Systems Integrated Roadmap*. The document

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<sup>38</sup> U.S. Air Force Safety Center, "Aircraft Statistics," January 2011. <http://www.afsc.af.mil/organizations/aviation/aircraftstatistics/index.asp> (accessed February 18, 2011)

<sup>39</sup> Kelly Pate. U.S. Army Roadmap, Full-Spectrum CABS Hot Topics at Army Aviation Convention, April 2010. <http://www.army.mil/-news/2010/04/15/37434-uas-roadmap-full-spectrum-cabs-hot-topics-at-army-aviation-convention/index.html> (accessed January 15, 2011).

<sup>40</sup> Market Research Media, "U.S. Military Unmanned Aerial Vehicles (UAV) Market Forecast 2010-2015," April 2010. <http://www.marketresearchmedia.com/2010/04/09/unmanned-aerial-vehicles-uav-market> (accessed January 15, 2011).

incorporates a vision and strategy for unmanned systems, identifying critical capabilities, and challenges for the next 25 years.

Other military services quickly followed suit with developing their own long-term UAS plans. In 2009, the Air Force released the *U.S. Air Force Unmanned Aircraft Systems Flight Plan 2009-2047*. In 2010, the Army released the *U.S. Army's Unmanned Aircraft Systems Roadmap 2010-2035*, and the U.S. Navy established a program office to manage its unmanned maritime vehicle (UMV) projects, combining advanced development and acquisition in a single shop.

The roles and functions of UAS are increasing. The DoD Quadrennial Defense Review (QDR), released in February 2010, called for “increased reliance on UAS for intelligence, surveillance, and reconnaissance (ISR).”<sup>41</sup> The DoD made a commitment to increase the capacity to 50 sustained orbits of Predator/Reaper UAS by FY 2011 to meet their counterinsurgency, stability, and counterterrorism operations.<sup>42</sup> Following the DoD’s lead, the Air Force is on track to achieve this goal and will continue to expand the force to 65 orbits by FY 2015.<sup>43</sup> The Army is also expanding all classes of UAS, including the accelerated production of the Predator-class Extended Range Multi-Purpose (ER/MP) UAS. The Navy is introducing sea-based UAS and the DoD is exploring ways to enhance the effectiveness of ISR aircraft by developing innovative sensor technologies, support infrastructures, and operating concepts.<sup>44</sup>

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<sup>41</sup> *Quadrennial Defense Review* (Washington: Government Printing Office, 2010), 22.

<sup>42</sup> Ibid.

<sup>43</sup> Ibid.

<sup>44</sup> Ibid.

The future for UAS looks promising. The introduction of Nano technology, improvement in networked systems, sensors, and security will lead the way to new innovations in UAS advancements. Future UAS will be able to perceive a specific situation and act independently with little or no human input while shortening decision time.<sup>45</sup>

The Air Force's long-term vision for UAS includes advances in artificial intelligence (AI) enabling the UAS to "make and execute complex decisions."<sup>46</sup> Through the use of AI, full autonomy can be achieved by reducing necessary time required to engage a target. Complexity of target identification, description, number of targets, environmental factors, friendly locations, collateral damage, rules of engagement, etc.... could all be computed instantaneously. Of course, legal, moral, and policy decisions will play a large roll in determining the use of AI in the future.

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<sup>45</sup> *U.S. Air Force Unmanned Aircraft Systems Flight Plan 2009-2047* (United States Air Force, Headquarters: Washington, DC, 2009), 16.

<sup>46</sup> *Ibid.*, 50.



## **CHAPTER 3**

### **OPERATIONAL ENVIRONMENT**

The National Airspace System (NAS) is one of the most complex and efficient airspace control systems in the world with the purpose to “safely facilitate air transportation and provide equitable access to both air and ground-side aviation resources.”<sup>1</sup> This chapter will identify current classifications of UAS, define the NAS operational environment, and identify operational requirements to operate within the NAS.





#### **Classifications of UAS**

There is no widely accepted classification system for UAS categories due to the wide range of operational characteristics, sizes, and capabilities of each system. With the lack of regulatory guidance, the FAA, DoD, and each service component have established their own criteria for UAS categories. When classifying UAS, most are described by use, operating altitude and weight. Using FAA, commercial, civil, and military literature, broad categories are used to simplify this study. The categories used are Very Low Altitude, Low Altitude, Medium Altitude Long Endurance (MALE), and High Altitude Long Endurance (HALE). A Heavy UAS was included due to the potential this class could emerge in the future. Table 1 further defines UAS classes, their characteristics, typical uses, and operational parameters within the NAS.

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<sup>1</sup> J.R. Hansman and E.W. Roland, *Safety Considerations for Operation of Unmanned Aerial Vehicles in the National Airspace System*, Report No. ICAT-2005-1, MIT International Center for Air Transportation, Department of Aeronautics & Astronautics (Massachusetts Institute of Technology, March 2005), 25.

Table 1: Classes of UAS

Name	Representative Aircraft	Typical Uses	Operating Altitudes
Very Low Altitude	 Raven	Reconnaissance & surveillance	Below 1,000
Low Altitude	 Shadow	Local Surveillance & Data gathering	Up to 18,000 Class E Airspace
MALE (Medium Altitude Long Endurance)	 Predator	Regional & National Surveillance & cargo transportation	18,000 – 60,000 (FL 600) Class A Airspace
HALE (High Altitude Long Endurance)	 Global Hawk	Regional, National & International - Surveillance, data gathering	Above FL 600 Above Class A Airspace
HEAVY (Potential)	 Commercial	National & International Cargo Transport	18,000 – FL 450 Class A Airspace

Source: Created by author using information from Hansman, J.R., and E.W. Roland, *Safety Considerations for Operation of Unmanned Aerial Vehicles in the National Airspace System* and data from Department of Defense, *FY2009-2034 Unmanned Systems Integration Roadmap*.

Under the guidance of the Vice Chairman of the Joint Chiefs of Staff (VCJCS), the Joint UAS Center of Excellence (JUAS COE) defined five distinct categories of UAS. These five categories are based on the existing regulatory FAA structure, into which all current military UAS can be placed (see table 2).<sup>2</sup> The ultimate goal of establishing these categories is to facilitate the development of regulations specifically for UAS operations.

<sup>2</sup> U.S. Department of Defense, *FY2009-2034 Unmanned Systems Integrated Roadmap*, (Washington: GPO, 2010), 96.

Table 2. Joint UAS Categories

UAS Category	Maximum Gross Takeoff Weight (lbs)	Normal Operating Altitude (ft)	Speed (KIAS)	Current/Future UAS Platform
Group 1	0-20	<1,200 Above Ground Level (AGL)	100 Knots	WASP III, Future Combat System Class I. TACMAV RQ-14A/B, BUSTER, BATCAM, RQ-11B/C, FPASS, RQ-16A, Pointer, Aqua/Terra Puma
Group 2	21-55	<3,500 AGL	250 Knots	Vehicle Craft UAS, Scan Eagle, Silver Fox, Aerosonde
Group 3	<1,320	<18,000 Mean Sea Level (MSL)	250 Knots	RQ-7B, RQ-15, STAUS, XPV-1, XPV-2
Group 4	>1,320	>18,000 MSL	No limit	MQ-5B, MQ-8B, MQ-1A/B/C, A-160
Group 5	>1,320	>18,000 MSL	No limit	MQ-9A, RQ-4, RQ-4N, Global Observer, N-UCAS
<p>Note: Lighter than air vehicles will be categorized by the highest level of any of their operating criteria.</p> <p>(1) Group 1 UA: Typically weighs less than 20 pounds and normally operates below 1200 feet AGL at speeds less than 250 knots.</p> <p>(2) Group 2 UA: Typically weighs 21-55 pounds and normally operates below 3500 feet AGL at speeds less than 250 knots.</p> <p>(3) Group 3 UA: Typically weighs more than 55 pounds but less than 1320 pounds and normally operates below 18,000 feet MSL at speeds less than 250 knots.</p> <p>(4) Group 4 UA: Typically weighs more than 1320 pounds and normally operates below 18,000 feet MSL at any speed.</p> <p>(5) Group 5 UA: Typically weighs more than 1320 pounds and normally operates higher than 18,000 feet MSL at any speed.</p>				

Source: U.S. Department of Defense, *FY2009-2034 Unmanned Systems Integration Roadmap*, Figure 4. JUAS CONOPS UAS Categories. 96-97.

## The National Airspace System

The NAS consists of many elements that define airspace from the surface to a designated position in space as well as all supporting components. Airports, FAA and DoD facilities such as air traffic control (ATC) towers, flight service stations (FSS) and the Air Traffic Control System Command Center are all part of the of the NAS. In addition, the NAS consists of radars, weather sites, aeronautical charts, and regulations and procedures that enable safe flight operations in the United States.

It is necessary to define the components of the NAS to understand the complexity and operational challenges to operate UAS within segregated and non-segregated airspace. First, UAS operations are principally restricted to segregated airspace. Segregated airspace is designed to safely separate UAS operations from civilian traffic and other unauthorized aircraft. Segregated airspace consists of three categories of special use airspace defined in Appendix 1, Classes of Airspace: restricted, warning, and prohibited areas. Non-segregated airspace is a widely used term for airspace where all traffic, including civil traffic, is authorized to fly. The fundamental difference between the two is that segregated airspace is developed uniquely for systems like the UAS, while non-segregated airspace would allow both manned and unmanned to fly together within the same airspace.

### **Airspace Classifications**

Currently, UAS operate primarily within segregated airspace. There are a few exceptions where the FAA allow UAS to operate within non-segregated airspace, but established requirements must be met. Each airspace classification presents unique challenges for UAS to operate within their boundaries to include: communications and radar requirements, specific entry requirements, and separation services provided by air traffic control (ATC).<sup>3</sup> The FAA's Aeronautical Information Manual (AIM) defines the boundaries and weather minimums for each class of airspace.<sup>4</sup> Within the NAS, there are four defined airspace types: controlled, uncontrolled, special use, and other airspace.

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<sup>3</sup> Hansman and Roland, 23.

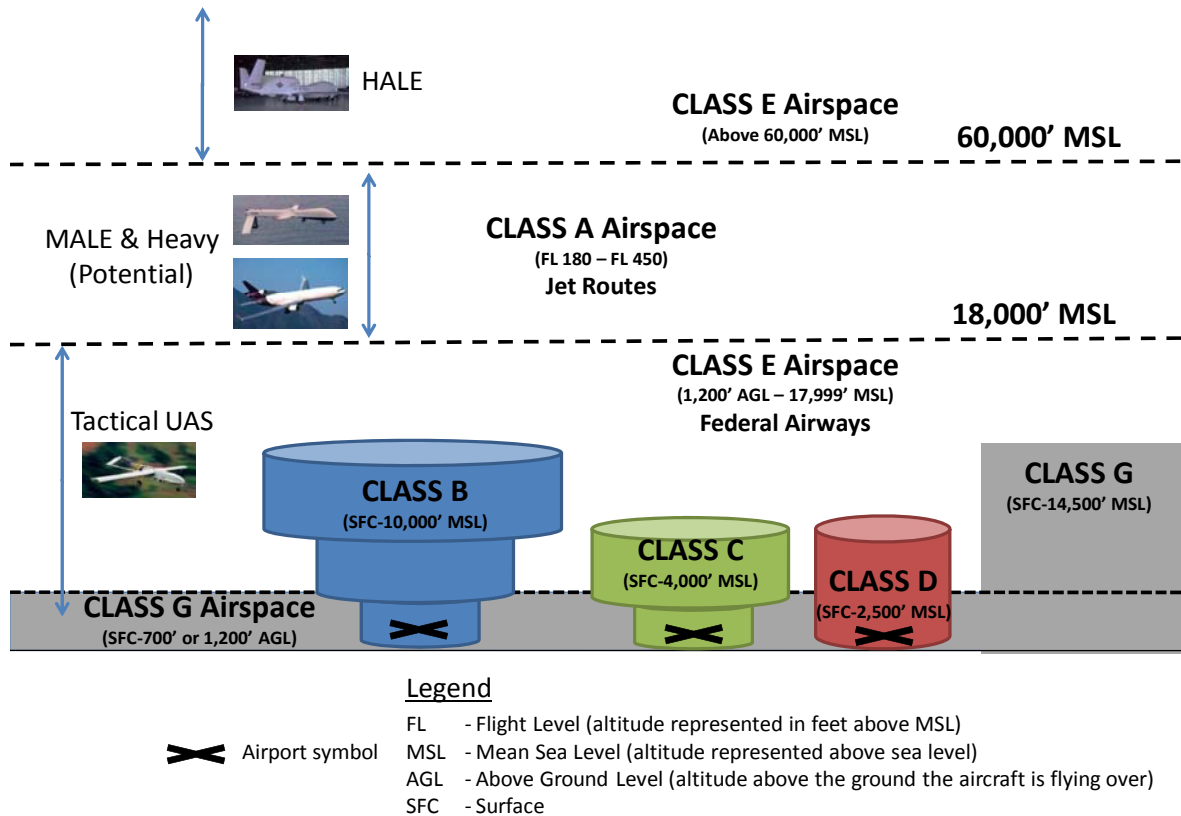
<sup>4</sup> Federal Aviation Administration. "Aeronautical Information Manual (AIM)," Chapter 3. [http://www.faa.gov/air\\_traffic/publications/atpubs/aim](http://www.faa.gov/air_traffic/publications/atpubs/aim) (accessed March 20, 2011).

Other airspace is not applicable to the majority of UAS operations in the NAS and therefore will not be discussed.

Controlled airspace is a term used to define airspace that is under the control of the FAA. This airspace was established to support high-volumes of air traffic using services provided by air traffic control facilities. There are currently five classes of controlled airspace depicted in Figure 1: Class A, B, C, D, and E. Each class of airspace has specific requirements that must be met before an aircraft can operate within their boundaries. These requirements are outlined in Title 14 of the Code of Federal Regulation and are further defined in Appendix 1, Classes of Airspace.

Uncontrolled airspace is a term used to define airspace where air traffic control services are not required due to lower volumes of aircraft and not in close proximity of large airports. The FAA has limited resources and by designating certain airspace as uncontrolled, resources can be distributed to areas more suited for higher volumes of traffic. There is currently only one class of uncontrolled airspace within the NAS, Class G (refer to Figure 1). Unlike controlled airspace, requirements to operate within uncontrolled are few and are further defined in Appendix 1, Classes of Airspace.

Figure 1: Visual chart of the FAA Airspace Classification.



Source: Created by author using data from the Federal Aviation Administration. "Aeronautical Information Manual (AIM)," Chapter 3.

In the NAS, the FAA has designated parts of controlled and uncontrolled airspace as Special Use Airspace (SUA). SUA consists of airspace of defined dimensions from the surface of the earth to designated vertical limits. Activities within the SUA are confined because of the nature of operations and to prevent non-participating aircraft incursions. The vertical limits of SUA are expressed as flight levels or as feet above mean sea level (MSL). The horizontal limits of SUA are measured by boundaries defined within geographic coordinates or other graphic references that define their dimension. All SUA will have a designated period of time, which the use of the airspace is in effect

usually stated in the designation.<sup>5</sup> SUA is divided into six separate types: prohibited, restrictive, warning, alert, military operations area, and controlled firing area. SUA is further defined in table 3, Airspace Classification Definitions.

### **Air Traffic System (ATS)**

The FAA is responsible for and manages the Air Traffic Control (ATC) system. The primary purpose of ATC is to prevent collision between aircraft operating in the NAS, to organize and expedite the flow of aircraft traffic, and provide support of National Security and Homeland Defense.<sup>6</sup> Airspace is divided into sectors and delegated to various ATC facilities within the NAS. Each ATC facility has the responsibility to provide aircraft separation, safety alerts and informational services to all users within their airspace. Procedural responsibilities of ATC are accomplished through ATC towers, enroute radar centers, radar approach facilities and flight service centers. Over 100,000 flights a day are controlled within the NAS by the Air Traffic System (ATS).

### **Operational Requirements**

Military UAS have operated within the NAS for the last 10 years, but those operations have been primarily confined to restricted and warning areas in segregated airspace. In response to the growing number of UAS and demand to operate within the NAS, the FAA published guidance in UAS Policy 05-01. In this policy, the FAA

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<sup>5</sup> U.S. Department of Transportation, *Special Use Airspace* Order JO 7400.8S (Washington, DC: Government Printing Office), §73.3.

<sup>6</sup> Federal Aviation Administration, *Air Traffic Control* Order 7110.65T (Washington, DC: Government Printing Office), 2-1-2.

published guidance for operating UAS within the NAS by defining a process for approval based on category of aircraft.

In order to operate a UAS within the NAS, the operator is required to establish UAS airworthiness either from FAA certification or a DoD airworthiness statement. Applicants must demonstrate that a collision with another aircraft or airspace user is not likely while complying with appropriate cloud and terrain clearance.<sup>7</sup> Additionally, the FAA establishes minimum qualifications and currency requirements of the person who controls the UAS. These requirements are further defined under a memorandum of agreement (MOA) between the FAA and DoD that will be further discussed in Chapter 4 of this research.

To operate above 18,000 feet MSL the UAS must be filed under Instrument Flight Rules, or IFR flight plan. Additionally, the UAS must obtain a clearance from Air Traffic Control (ATC), be equipped with an operational Mode C transponder, operate with operational navigation or collision avoidance lights, and maintain communications between the operator and ATC.

For flights below 18,000 feet MSL the UAS must meet the same requirements, except if the operator chooses to operate on other than an IFR flight plan, they may be required to pre-coordinate with ATC.<sup>8</sup> For recreational use, FAA Advisory Circular (AC) 91-57 generally “limits operations below 400 feet above ground level (AGL) and away from airports and air traffic.”<sup>9</sup>

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<sup>7</sup> General Operating and Flight Rules, *U.S. Code of Federal Regulations*, 14, Part 91 (2011), 3.

<sup>8</sup> *Ibid.*, 3.

<sup>9</sup> Federal Aviation Administration. “Fact Sheet: Unmanned Aircraft Systems (UAS).” [http://www.faa.gov/news/fact\\_sheets/news\\_story.cfm?newsId=6287](http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=6287) (accessed January 5, 2011).



In the following chapter, the author will conduct further analysis of current challenges and gaps that exist with integrating UAS in the NAS. Defining the operational environment upfront was essential to fully understand the complexity of manned and unmanned aircraft integration.

## CHAPTER 4

### ANALYSIS AND DISCUSSION

Outlined in the 2010 Quadrennial Defense Review, the DoD determined it was necessary to increase the overall capacity of UAS operations in support of current operational demands. They are exploring ways to enhance the effectiveness of their UAS fleet by developing innovative sensor technologies, support infrastructures, and operating concepts.<sup>1</sup> Following DoD's lead, the Air Force and Army are expanding their fleet of UAS through the year 2035 while the Navy is looking to introduce sea-based UAS.

To keep pace with the DoD's UAS expansion out to 2035, unmanned and manned flight must share the same airspace. Additionally, to maintain a high degree of combat readiness, COCOMs need to conduct realistic UAS and integrated training (i.e. manned-unmanned teaming) in the NAS prior to operational missions.<sup>2</sup> An analysis of DoD, FAA and Joint Publications will reveal current airspace integration and capabilities gaps that continue to impede integration.

This chapter will discuss the fundamental challenges facing the FAA and DoD with integrating manned and unmanned aircraft in the same airspace. In order to meet FAA requirements, there are four primary challenges that must be addressed in order to successfully integrate UAS into non-segregated portions of the NAS: safety standards, regulatory challenges, technical challenges, and operational challenges.

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<sup>1</sup> *Quadrennial Defense Review* (Washington: Government Printing Office, 2010), 22.

<sup>2</sup> U.S. Department of Defense, *Final Report to Congress, Access to National Airspace for Unmanned Aircraft Systems* (Washington, DC: 2010), 9. [www.acq.osd.mil/psa/docs/report-to-congress-ana-for-uas.pdf](http://www.acq.osd.mil/psa/docs/report-to-congress-ana-for-uas.pdf) (accessed March 15, 2011).

## **Safety Standards**

The FAA's main concern with integrating manned and unmanned aircraft within the same airspace is safety. On an average day in the NAS there are more than 100,000 aviation operations, including commercial air traffic, cargo operations, and business jets. Additionally, there are more than 238,000 general aviation aircraft in the NAS at any given time.<sup>3</sup> To successfully integrate UAS operations in the NAS, they must meet and exceed safety standards for manned aircraft established by the FAA. These standards primarily focus on aircraft reliability and airworthiness. Aircraft reliability and airworthiness are critical in ensuring people and properties in the air and on the ground are not at risk of injury. UAS must be able to operate seamlessly with manned aircraft without threatening the overall safety of the airspace.

The following analysis of safety standards will reveal gaps in three areas. First, lack of data exists to successfully establish a target level of safety (TLS) for UAS operations within the NAS. Second, unmanned aircraft are not fully meeting the same level as manned aircraft reliability standards. Finally, the requirement for DoD UAS to meet FAA Airworthiness standards for civilian aircraft.

### **Target Level of Safety (TLS)**

The fundamental safety requirements for manned and unmanned aircraft are to provide an acceptable level of risk to people and property. To effectively integrate UAS within the NAS, the FAA and DoD must establish a target level of safety (TLS) that is acceptable to the general public.

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<sup>3</sup> Federal Aviation Administration. "Fact Sheet: Unmanned Aircraft Systems (UAS)." [http://www.faa.gov/news/fact\\_sheets/news\\_story.cfm?newsId=6287](http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=6287) (accessed January 5, 2011).

It is difficult to establish a TLS for manned and unmanned aircraft integration. Limited data exist and without it, one cannot successfully formulate a reliable safety baseline. Therefore it is necessary to define a set of measureable performance standards to determine if UAS can safely integrate within the NAS.

The primary policy governing safety risk management and system safety is formal in FAA Order 8040.4, dated June 1998, and the Acquisition Management System (AMS). Both documents require FAA-wide implementation of safety risk management in a “formalized, disciplined, and documented manner for all high-consequence decisions.”<sup>4</sup> Not intended to interfere with regulatory processes, FAA Order 8040.4 was designed to take a common sense approach to safety and risk management. Information obtained from the safety risk management process can enable the FAA and DoD to communicate effectively to the general public.

FAA Order 8040.4 provides an outline for safety risk management consisting of a five-step process: plan, hazard identification, analysis, assessment, and decision.<sup>5</sup> This outline is an effective tool already used in establishing a TLS for manned aircraft flight and can also be used for UAS. As stated earlier, there is minimal safety data on integrating manned and unmanned aircraft within the NAS. Therefore it is recommended that data collected from the wars in Iraq and Afghanistan be used to formulate a safety baseline.

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<sup>4</sup> U.S. Department of Transportation, *FAA Safety Risk Management*, Order 8040.4 (Washington, DC: 1998) 2.  
[http://rgl.faa.gov/regulatory\\_and\\_guidance\\_library/rgorders.nsf/0/56a31d47665d804b8625723500611f8e/\\$FILE/ND8040-4.pdf](http://rgl.faa.gov/regulatory_and_guidance_library/rgorders.nsf/0/56a31d47665d804b8625723500611f8e/$FILE/ND8040-4.pdf) (accessed February 15, 2011).

<sup>5</sup> Ibid., 6.

Defining an acceptable level of safety risk or TLS must become more standardized to alleviate confusion between DoD and the FAA. Planned UAS operations within the NAS should undergo a detailed safety risk assessment to consider all potential hazards in the air and on the ground. As a minimum, data obtained from UAS deployments in Iraq and Afghanistan could provide a foundation for determining TLS.

### **System Reliability**

For the FAA and DoD, UAS reliability is the first challenge in integration because it “underlines UAS acceptance into civilian airspace.”<sup>6</sup> Historically, UAS have experienced a mishap rate twice the rate of manned aircraft. Although in recent years improvements in technology and procedures have narrowed the mishap rate almost on par with manned aircraft, UAS system reliability is still a major concern of the FAA. Recent UAS control issues highlighted in the news media continually overshadow improvements in UAS reliability.

On August 2, 2010, a small windowless helicopter named the MQ-8B Fire Scout UAS operated by the U.S. Navy flew within 40 miles of Washington D.C.’s restricted airspace before operators could stop it. Naval officials could not say if anyone was alarmed by the incident but believed the problem with the MQ-8B Fire Scout Vertical Takeoff and Landing UAS was due to software issues.<sup>7</sup> Recent incidents like this are examples of continued concerns the FAA and the general public have with UAS reliability.

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<sup>6</sup> U.S. Department of Defense, *FY2009-2034 Unmanned Systems Integrated Roadmap*, (Washington: GPO, 2010), 92.

<sup>7</sup> CIKR Monthly Open Source Cyber Digest, Office of Infrastructure Protection, *Navy Drone Wanders into Restricted Airspace around Washington*. August 2010. [http://www.fbiic.gov/public/2010/sep/Cyber\\_Digest\\_August\\_2010\\_FINAL.PDF](http://www.fbiic.gov/public/2010/sep/Cyber_Digest_August_2010_FINAL.PDF) (accessed January 5, 2011).

The U.S. Army Combat Readiness Center has been collecting data on manned and unmanned aerial systems for several years. Statistical analysis was collected on each flight mishap for each system using the DoD accident classification system (Class A-E).

Flight mishaps involve any reportable damage to an aircraft that is preparing to fly, in flight, or completing a landing. The DoD classifies flight mishaps according to the severity of resulting injury or property damage. Class A mishaps involve damage of \$1 million or more, a destroyed aircraft, or a fatality or permanent total disability. The remaining classes of mishaps are distinguished primarily by their loss value and severity of injury.<sup>8</sup>

Class B accidents involve damage ranging from \$200,000 to less than \$1 million, permanent partial disability, or inpatient hospitalization of five or more people. Class C accidents involve damage ranging from \$10,000 to less than \$200,000 or a lost-time injury, and Class D accidents involve damage of less than \$10,000. DoD requires that all mishaps be investigated so that causes can be identified and corrective actions taken to prevent future occurrences.<sup>9</sup> Service safety centers play a key role in maintaining aviation mishap statistics, establishing safety policies, disseminating safety information, reviewing mishap investigation reports, tracking recommendations, and performing safety studies. In addition, the safety centers analyze trends to identify potential safety hazards.<sup>10</sup>

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<sup>8</sup> U.S. Department of Defense, *Accident Investigation, Reporting, and Record Keeping*, DODI 6055.07 (Washington, DC: Government Printing Office). October 3, 2000, incorporating Change 1, April 24, 2008, 8.

<sup>9</sup> Ibid.

<sup>10</sup> Ibid.

Aviation accident trends since 2006 provided by the U.S. Army Combat Readiness Center show that although the UAS accident rate were almost on par with manned aircraft in 2006, improvements in reliability and procedures have reduced accident rates well over 50%.<sup>11</sup> The two tables below compare the Fiscal Year (FY) 2010 accident statistics to the previous four FYs covering the same period. Analysis of the data shows that the UAS accident rates decreased by over 75% while manned aircraft accidents rates decreased by only 30% over the four year period.

Table 3. U.S. Army Manned Aircraft Accident Statistics

Fiscal Year	# Class A	# Class B	# Class C	Total A-C
10	20	12	40	72
09	21	21	86	128
08	18	13	82	113
07	27	13	74	114
06	21	17	65	103

Source: Created by author from data obtained from the U.S. Army Combat Readiness/Safety Center.

Table 4. U.S. Army Unmanned Aircraft Accident Statistics

Fiscal Year	# Class A	# Class B	# Class C	Total A-C
10	6	7	17	30
09	4	16	21	41
08	8	21	47	76
07	5	19	46	70
06	4	41	76	121

Source: Created by author from data obtained from the U.S. Army Combat Readiness/Safety Center.

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<sup>11</sup> Information provided in email from LTC David Fleckenstein, Director, Air Task Force, U.S. Army Combat Readiness/Safety Center, Fort Rucker, AL., September, 2010.

Information obtained from the U.S. Air Force Safety Center reveals through analysis of total aircraft accidents (table 5) compared with unmanned systems (table 6) significant reduction of UAS accident rates.<sup>12</sup> Compared with the U.S. Army aircraft accident rates for UAS, the Air Force's accident rate reduction is on par.

Table 5. U.S. Air Force Total Aircraft Accident Statistics

Fiscal Year	# Class A	# Class B	Total A-B
10	14	37	51
09	17	106	123
08	26	87	113
07	27	86	113
06	19	71	90

Source: Created by author from data obtained from the U.S. Air Force Safety Center.

Table 6. U.S. Air Force Unmanned Aircraft Accident Statistics

Fiscal Year	# Class A	# Class B	Total A-B
10	0	0	0
09	17	4	21
08	12	3	15
07	6	0	6
06	5	0	5

Source: Created by author from data obtained from the U.S. Air Force Safety Center.

According to the Air Force Safety Center, accident rates per 100,000 hours dropped to 7.5 for the Predator and 16.4 for the Reaper in 2009. The Predator rate is comparable to that of the F-16 fighter at the same stage and just under the 8.2 rates for small, single-engine private airplanes flown in the U.S.

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<sup>12</sup> U.S. Air Force Safety Center, *Aircraft Statistics*, <http://www.afsc.af.mil/organizations/aviation/aircraftstatistics/index.asp> (accessed February 18, 2011).



The DoD is addressing UAS reliability challenges. Coordination between military services, contractors, and manufacturers to use redundant, fail-safe designs has made numerous improvements with standardization of ground control systems. Additionally, a federal advisory body is developing technical standards for UAS. However, Department of Homeland Security's Transportation Security Administration has not yet provided their own analysis of the security implications of routine UAS access to the NAS.

Both services' statistics have shown that reliability for UAS operations have gained positive results in the last five years. Improvements in reliability can be attributed to gained experience and improved technologies that is approaching an equivalent level to manned aircraft. UAS reliability must continue to improve and be equal to or greater than manned aircraft to gain support for integration into the NAS.

### **Airworthiness Certification**

Airworthiness certification is vital for UAS expansion into the NAS and ensures that aircraft will "minimize potential hazard to aircrew, passengers, people, and property on the ground."<sup>13</sup> Statistics obtained from the U.S. Army UAS Roadmap show that from 1982-2000, an average of 2.2 percent of all aviation fatalities involved people hurt from parts falling off aircraft.<sup>14</sup> Though the percentage of fatalities directly related to airworthiness appears to be low, percentage levels are expected to increase with full access to the NAS and flights over populated areas. Therefore, UAS must maintain the

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<sup>13</sup> *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army* (Fort Rucker, AL: US Army Unmanned Aircraft Systems Center of Excellence, 2010), 109.

<sup>14</sup> *Ibid.*

same airworthiness standards as manned aircraft without increasing concerns from the public.

The term “airworthy” is not defined in title 49, United States Code (49 U.S.C.), or in title 14 Code of Federal Regulations (CFR); however, a clear understanding of its meaning is essential for use in the FAA and DoD’s airworthiness certification programs.<sup>15</sup>

A review of case law relating to airworthiness reveals two conditions that must be met for an aircraft to be considered airworthy. First, the aircraft must conform to its type certificate (TC). Conformity is met when the aircraft configuration and the engine, propeller, and articles installed are consistent with the drawings, specifications, and other data. This would also include any supplemental type certificate (STC) and field approved alterations incorporated into the aircraft. Second, the aircraft must be in a condition for safe operation. This refers to the condition of the aircraft relative to wear and deterioration, for example, skin corrosion, window delamination/crazing, fluid leaks, and tire wear. If either one or both of these conditions were not met, the aircraft would be classified as un-airworthy.<sup>16</sup>

The FAA classifies aircraft into two separate categories: public and civilian. In accordance 14 CFR, all Armed Forces owned or contracted aircraft are classified as public aircraft.<sup>17</sup> All other aircraft, not defined as public, are classified as civilian

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<sup>15</sup> U.S. Department of Transportation, *Airworthiness Certification and Related Products*, Order 8130.2F Change 5 (Washington, DC: 2010), 6.  
[http://rgl.faa.gov/Regulatory\\_and\\_Guidance\\_Library/rgOrders.nsf/0/77A132602A4E1F9A862576B3005D253D?OpenDocument](http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgOrders.nsf/0/77A132602A4E1F9A862576B3005D253D?OpenDocument) (accessed February 20, 2011).

<sup>16</sup> Information in this paragraph was obtain in the U.S. Department of Transportation, *Airworthiness Certification and Related Products*, Order 8130.2F Change 5 (Washington, DC: 2010), 7.

<sup>17</sup> Definitions and Abbreviations, *U.S. Code of Federal Regulations*, 14, Part 1 (2011).

aircraft. The difference is classification allows the DoD to certify their own aircraft to meet mission requirements without fully complying with current Federal Aviation Regulations (FARs) outlined in 8110.4C, *Type Certification Process*. To date, only the Global Hawk UAS has completed the certification process and been granted an airworthiness certification.

The DoD has their own internal airworthiness certification and flight release processes governed by MIL-HDBK-516B, *Airworthiness Certification Criteria*. This document establishes the criteria and basis for determining airworthiness for all DoD manned and unmanned systems. The DoD airworthiness process is defined as three separate levels based on safety of flight (SOF) risks (refer to Appendix 2, Levels of Airworthiness). Level 1 certifies to standards equivalent to manned systems with catastrophic failure rates no worse than one loss per 100,000 flight hours. Level 2 authorizes standards less stringent for unmanned aircraft with catastrophic failed rates no worse than one loss per 10,000 flight hours. Level 3 minimizes catastrophic failed rates to less than 1,000 flight hours.<sup>18</sup>

Analysis of FAA and DoD regulations addressing airworthiness certification reveals two potential gaps within the certification process. First, airworthiness certification standards for UAS are not fully compliant with manned aircraft. SOF risks are not directed at governing UAS flight and only reference loss of aircrew for manned flight. Additionally, SOF risks associated with personnel, damage to equipment,

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<sup>18</sup> Levels of Airworthiness obtained from the *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army* (Fort Rucker, AL: US Army Unmanned Aircraft Systems Center of Excellence, 2010), 109-110.

property, and/or environment must be considered when establishing certification standards.<sup>19</sup>

Second, is the purchase and certification of commercial derivative aircraft (CDA) by the DoD. CDA are commercially produced “off the shelf” aircraft with a FAA approved certificate of airworthiness under civil aircraft rules. The Armed Services typically purchase CDA to reduce cost, maintenance, and time to the user. Once CDA are purchased by the Armed Services, alterations can be accomplished under public aircraft rules. Any non-FAA approved alteration to a CDA will render FAA airworthiness certifications invalid. Modification of FAA approved CDA by DoD could pose a threat to overall safety standards.

Gaps in DoD and FAA airworthiness certification standards present an enormous challenge. The eventual redeployment of over 4,000 plus UAS from Afghanistan and Iraq will require access to the NAS. The FAA and DoD must be prepared to overcome these gaps in airworthiness certification procedures to successfully integrate UAS within the NAS. UAS must meet the same standards as manned aircraft to operate in close proximity of populated area.

### **Regulatory Challenges**

The FAA has sole authority over the safe and efficient use of the NAS. The FAA’s policies and air traffic regulations are meant to ensure the safety of the citizens of the United States while ensuring safe aircraft operations within the NAS. Strict rules are enforced and followed to meet regulatory safety guidelines. The Federal Aviation Act of

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<sup>19</sup> Levels of Airworthiness obtained from the *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army*, 109-110.

1958 directed the FAA as the “single manager” of the NAS and to develop a common system of control to manage the safe flight of both civilian and military aircraft.<sup>20</sup> U.S.C. 49, 40101 Policy charges the FAA administrator with the same responsibilities as the Secretary of Transportation with the added task of “enhancing safety.” U.S.C. 49, 40101. Policy states the administrator shall consider the following matters, among others, as being in the public interest:

- (1) Assigning, maintaining, and enhancing safety and security as the highest priorities in air commerce.
- (2) Regulating air commerce in a way that best promotes safety and fulfills nation defense requirements.
- (3) Encouraging and developing civil aeronautics, including new aviation technology.
- (4) Controlling the use of the navigable airspace and regulating civil and military operations in that airspace in the interest of the safety and efficiency of both of those operations.
- (5) Consolidating research and development for air navigation facilities and the installation and operation of those facilities.
- (6) Developing and operating a common system of air traffic control and navigation for military and civil aircraft.
- (7) Providing assistance to law enforcement agencies in the enforcement of laws related to regulation of controlled substances, to the extent consistent with aviation safety.<sup>21</sup>

As a result of mounting pressure from the U.S. Congress, the DoD and FAA signed a restrictive memorandum of agreement (MOA) in September 2006 to ensure that UAS operations were conducted safely, efficiently and in accordance with U.S. law. Additionally, the MOA ensured UAS access to the NAS for domestic operations, including the War on Terror, as long as specified requirements were met. The MOA was restrictive in nature and ensured the FAA would maintain oversight of the DoD UAS

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<sup>20</sup> Federal Aviation Act of 1958, *United States Code*, 14, sec. 303(e) (1958), 24. <http://libraryonline.erau.edu/online-full-text/books-online/Aviationlawpt1.pdf> (accessed December 15, 2010).

<sup>21</sup> Aviation Programs, *United States Code*, 49, sec. 40101: Policy, Subtitle VII (2001), 2. [http://www.tsa.gov/assets/pdf/49\\_USC\\_Chapters\\_401\\_to\\_501.pdf](http://www.tsa.gov/assets/pdf/49_USC_Chapters_401_to_501.pdf) (accessed March 20, 2011).

program. For all UAS operations that operate under this MOA, the DoD must notify the FAA in advance and publish Notices to Airmen (NOTAMS) to alert non-participating aircraft of the flights.

In 2008, the U.S. Congress sensed that progress was lagging in the integration of UAS in the NAS for operational training, operational support to the Combatant Commanders in the United States, and support to domestic authorities in emergencies and natural disasters. Congress recommended that the DoD and the FAA form an Executive Committee to act as a focal point for resolution of issues on matters of policy and procedures relating to UAS access to the NAS. The Duncan Hunter National Defense Authorization Act (NDAA) suggested that techniques and procedures should be rapidly developed to temporarily permit the safe operation of public UAS within the NAS.

In 2010, the FAA formed a collaborative partnership with the DoD, the Department of Homeland Security (DHS), and the National Aeronautics and Space Administration (NASA), called EXCOM. Its goal is to develop a National Airspace Access Plan for UAS. The plan will include near-term, mid-term and far-term goals and objectives through 2025.<sup>22</sup> Although EXCOM's goal is clear, there is no established timeline by the FAA to have the National Airspace Access Plan completed.

Though UAS operate routinely in combat zones, flights within the NAS have many restrictions. One of the major challenges to successfully integrate UAS within the NAS is the ability to comply with requirements levied by the FAA in Federal Aviation Regulations (FARs). FARs consists of five separate volumes expanding over 1399 parts in Title 14 of the Code of Federal Regulations. The extensive lists of FARs provide the

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<sup>22</sup> *National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2010*, Public Law 111-84, Section 935(c) (2009). [http://intelligence.senate.gov/pdfs/military\\_act\\_2009.pdf](http://intelligence.senate.gov/pdfs/military_act_2009.pdf) (accessed January 15, 2011).

national implementing requirements for registration, airworthiness certification, licensing of personnel, and rules of the air. Current FAR requirements do not consider UAS operations and were predominately developed for manned aircraft.

Analysis of Title 14 CFR concluded that there was no regulatory definition of UA or UAS. Additionally, the only general working of definition of an unmanned aircraft was found in FAA AFS-400 UAS Policy 05-01. Difficulty in interpretation and application of the regulations to UAS operations relies on referring unmanned aircraft as “aircraft,” which is defined in 14 CFR 1.1.

A study conducted in 2009 for the Department of Transportation examined sections of 14 CFR to assess the applicability to UAS operating in the NAS. The results were categorized into four levels: clearly applies, may apply by interpretation, does not apply, and could apply with revisions.<sup>23</sup> The review of 436 separate items contained within the 14 CFR revealed that only 30% applied to UAS operations within the NAS using “aircraft” to define UAS since it is not explicitly defined in the 14 CFR.

The Department of Transportation also reviewed other relevant documents to include FAA Advisory Circulars, Technical Standard Orders, and Airman Information Manuals. In the extensive review of all documents only 33% applied to UAS.<sup>24</sup> The inability of the FAA to clearly define UAS operations in the NAS continues to impede successful integration with manned flight.

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<sup>23</sup> U.S. Department of Transportation. *Unmanned Aircraft Systems Regulation Review*, (Washington, DC: Government Printing Office), 4. [www.tc.faa.gov/its/worldpac/techrpt/ar097.pdf](http://www.tc.faa.gov/its/worldpac/techrpt/ar097.pdf) (accessed February 14, 2011).

<sup>24</sup> Ibid., 12.

## Registration Requirements

All flight in the United States NAS is regulated or coordinated with the FAA under jurisdiction granted by law. In 1999, a joint venture between the DoD and the FAA resulted in the establishment of the Certificate of Authorization (COA).<sup>25</sup> The COA is an exception to current regulations that allows UAS to fly within the NAS with specified restrictions.

Regional FAA authorities, resulting in different standards depending upon the approving authority, must review each unmanned aircraft COA. Additionally, differences in procedures are introduced between civil and military UAS operations, which are also approved through separate FAA departments. The process is inefficient, and does not result in clear standards for users to follow in designing UAS applications.

The COA authorizes an operator to use approved and designated airspace for a specific time period usually lasting up to one year. Almost all COAs require prior coordination with appropriate air traffic control (ATC) facilities and require an operational transponder that allows ATC to track the UAS while in flight. Additionally, UAS are required to maintain an observer, either on the ground or in a chase aircraft, to maintain visual contact with the UAS at all times.

Although the COA does provide an opportunity to gain access to the NAS, the process is extremely time consuming and inefficient. COA approval can take up to 60 days and because of current FAA restrictions, can require chase planes and/or primary radar coverage.<sup>26</sup>

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<sup>25</sup> Federal Aviation Administration. "Aeronautical Information Manual (AIM)," Chapter 3. [http://www.faa.gov/air\\_traffic/publications/atpubs/aim](http://www.faa.gov/air_traffic/publications/atpubs/aim) (accessed March 20, 2011).

<sup>26</sup> *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army*, 105.



The number of COAs issued by the FAA has grown significantly in recent years including: 85 COAs issued in calendar year (CY) 2007, 164 COAs issued in CY 2008, and 146 COAs issued in CY 2009. As of August 2010 the agency has issued 268 COAs.<sup>27</sup>

Although the COA request rate has doubled for the last three years, the FAA is still reluctant to allow integration of manned and unmanned aircraft. The FAA believes the UAS still lacks the ability to meet the same regulatory requirements as a manned aircraft. The COA is a conservative approach in ensuring safety. UAS flights are often limited to a designated and approved area of operation and must adhere to a pre-determined flight routes.

In September 2006, the Deputy Secretary of Defense directed the DoD Policy Board on Federal Aviation to construct an agreement with the FAA to allow ready access to the NAS for DoD UAS domestic operations.<sup>28</sup> The FAA agreed to provide access to the NAS outside of Restricted and Warning Areas if the DoD could meet specified requirements for Class D and G airspace. For Class D airspace, the DoD must ensure that UAS operations are not conducted over populated areas or within airspace outlined in 14 CFR 91.215, *ATC Transponder and Altitude Reporting Equipment and Use*. In accordance with this CFR, UAS cannot operate within Class A, B, and C airspace or within 30 nautical miles from populated areas without an operational transponder device capable of reporting aircraft flight altitude.<sup>29</sup>

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<sup>27</sup> FAA. "Fact Sheet: Unmanned Aircraft Systems (UAS)."

<sup>28</sup> Memorandum of Agreement (MOA) Concerning the Operation of Department of Defense Unmanned Aircraft Systems in the National Airspace, September 2007, 1.

<sup>29</sup> *Ibid.*, 2.

Second, UAS that are categorized as Group 1, weighing 20 pounds or less (see table 2, pg. 22), can operate within Class G airspace below 1,200 feet AGL. This second condition is not applicable to airspace identified in 14 CFR 91.215. Group 1 UAS must remain within clear visual range of the pilot, or certified observer in ready contact with the pilot, to ensure separation from other aircraft. Additionally, DoD will ensure the UAS remains more than five miles from any civil use airport or heliport.<sup>30</sup>

### Rules of the Road

Unmanned aircraft must comply with several CFR depending on the class of airspace they intent to operate within the NAS. To operate within Class A airspace, normally reserved for jet routes (see figure 1, page 25), all UAS operations must be filed under an instrument flight plan.<sup>31</sup> The Air Force is the primary user of Class A airspace because the altitudes they fly with HALE and MALE UAS.

Unmanned flights are not currently authorized within Class B airspace (see figure 1, page 25). Class B airspace contains terminal areas with the highest density of manned aircraft in the National Airspace System. Class B airspace includes the largest airports in our Nation. The FAA will consider exceptional circumstances to allow UAS access to Class B airspace but due to the high concentration for manned aircraft, it is not likely.

The FAA handles request for approval to fly within Class C and D airspace on a case-by-case basis. In order for the DoD to successfully gain access into Class C or D airspace, they must show they can mitigate any potential risk to personnel and property.<sup>32</sup>

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<sup>30</sup> MOA Concerning the Operation of DoD UAS in the National Airspace, September 2007, 2.

<sup>31</sup> Operations in Class A Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 135 (2011).

<sup>32</sup> Operations in Class C Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 130 (2011) and Operations in Class D Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec 129 (2011).

Class C airspace requires compliance with equipment outlined in 14 CFR 91.215 (see Appendix 1, Airspace Classifications) and cannot be waived.<sup>33</sup> Aircraft equipped with position and altitude-reporting equipment, like transponders, are required to provide air traffic control agencies information to mitigate potential hazards in flight.

Unmanned aircraft operating within Class E or G airspace must comply with their respective CFR. Additionally, if Class E airspace has an operational control tower, UAS must comply with Class D airspace requirements.<sup>34</sup>

Class B, C, and D airspace is defined by the boundaries of surrounding airports (terminal airspace) where increased mid-air collision between aircraft exists. The classes A, E, and G airspaces are not defined by surrounding airports but relate to altitude and the mode of flight operations that commonly occur at those altitudes (en route airspace). To ensure safety standards are maintained in Classes A, B, and C airspace, separation services and advisories are provided by Air Traffic Control (ATC) to all flights. ATC will also provide similar flight separation services in Class E but do not provide service to Class G airspace.

It is important to note that regardless of the class of airspace, or whether ATC procedures are used to maintain aircraft separation, pilots are required to see and avoid any potential collision with other aircraft.<sup>35</sup> Until UAS specific regulations are defined, it will be difficult to establish regulatory compliance for routine UAS access in the NAS.

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<sup>33</sup> Air Traffic Control Transponder and Altitude Reporting Equipment Use, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 215 (2011).

<sup>34</sup> Operating on or in the Vicinity of an Airport in Class E Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 127 (2011) and Operating on or in the Vicinity of an Airport in Class G Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 126 (2011).

<sup>35</sup> Right-of-Way Rules, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 113 (2011).

## **Technical Challenges**

To gain routine access to the NAS all aircraft must comply with Title 14 CFR 91.113, *Right of Way Rules: Except Water Operations*. Outlined within this CFR, aircraft must have the ability to sense and avoid other aircraft operating within the same airspace.<sup>36</sup> For UAS to successfully operate within the guidance of Title 14 CFR 91.113, they must meet minimum performance and equipage requirements for each class of airspace. UAS Compliance with this CFR is difficult since the fundamental principle for flying unmanned aircraft is the pilot's ability to control the aircraft from a location not in close proximity of the aircraft.

The following analysis will reveal three key gaps required to solve for successful integration of UAS into the NAS. First, the DoD and FAA must address challenges with sense and avoid technology. Second, current surveillance systems used by ATC to maintain contact with flying aircraft must be updated. Finally, frequency and bandwidth management must expand to include future UAS operations in the NAS.

### **Sense and Avoid (SAA) Technology**

Collision avoidance is, and always will be, an area of prominent concern for the FAA. Operating an aircraft in the NAS carries the same responsibilities as operating a car on the road. Collision avoidance is the primarily responsibility of the pilot or driver of the vehicle. Because the pilot of a UAS isn't co-located with the aircraft, collision avoidance is severely limited compared to manned flight. A pilot's use of sight is the best means to deter potential collisions in the air. As an alternative to sight, many

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<sup>36</sup> Right-of-Way Rules, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 113 (2011).

manned aircraft are equipped with sense and avoid (SAA) technology that can provide early warning to pilots of potential collisions in the air with other aircraft.

Currently, the FAA does not recognize UAS operating in the NAS as having SAA capability. Integration of UAS into non-segregated airspace has been hindered by the systems inability to comply with Title 14 CFR Part 91.111 and 91.113. Both documents require that, whether filed under instrument flight rules (IFR) or visual flight rules (VFR), “vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft.”<sup>37</sup> The ability to sense and avoid other aircraft is paramount for the safety of all participating and non-participating aircraft. The Army and the Air Force argue that “the purpose of the this regulation is to avoid mid-air-collisions, therefore the focus should be on technological efforts to address issues as it relates to UAS rather than trying to mimic and/or duplicate human vision.”<sup>38</sup>

Recognizing the importance of developing common autonomous SAA capability for unmanned aircraft, DoD created an Airspace Integration (AI) Integrated Product Team (IPT) within the UAS Task Force to focus on and coordinate airspace integration efforts.<sup>39</sup> The AI IPT identified SAA capabilities necessary to gain NAS access through special rules and policy, new procedures, and use of ground/air based sensor technology. Although the AI IPT is continuing to work solutions for UAS to access the NAS, there is still no accepted standard between the FAA and DoD for UAS sense and avoid equipment.

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<sup>37</sup> Operating Near Other Aircraft, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 111 (2011) and Right-of-Way Rules, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 113 (2011).

<sup>38</sup> *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army*, 111.

<sup>39</sup> Sharon Pickup, *Unmanned Aircraft Systems Comprehensive Planning and Results-Oriented Strategy are needed to Support Growing Inventories*, (Washington, DC: Government Accountability Office, March 2010), 6.

Looking for alternate means of compliance to the FAA's SAA requirements, the Army's UAS Project Office (PO) has established the Unmanned Systems Airspace Integration Concepts Product Directorate (USAIC PD) for the specific purpose of developing, testing, fielding, and sustaining a ground-based sense and avoid (GBSAA) program.<sup>40</sup> The GBSAA would give UAS operators a SAA capability, allowing them an alternate means of compliance with 14 CFR Part 91.113.

The Air Force and Navy are the lead services pursuing an air-based sense and avoid (ABSAA) solution that will integrate with the GBSAA. Initially, the system will leverage Group 5 UAS capabilities, like the RQ-4B and BAMS, and will be expanded to include Groups 3-4. Efforts are focused on developing the capability to perform both self-separation and collision avoidance onboard unmanned aircraft to ensure an appropriate level of safety.

The further development of both systems will require the need to assess equipment and procedure that are necessary to integrate into FAA's Next Generation Air Transportation System (NextGen) discussed further in surveillance systems.

## **Surveillance Systems**

Current systems used by the FAA and ATC to maintain situational awareness of aircraft position while flying in segregated airspace involves the use of radar. Radar is a method whereby radio waves are transmitted into the air and are then received when they have been reflected by an object in the path of the beam. Range is determined by measuring the time it takes (at the speed of light) for the radio wave to go out to the

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<sup>40</sup> Trey Kelly, "Meeting Acquisition Challenges Presented by the Army's Ground-Based Sense and Avoid (GBSAA) and Airspace Integration (AI) Efforts," *Army AL&T*, (January-March 2010): 7.

object and then return to the receiving antenna. The direction of a detected object from a radar site is determined by the position of the rotating antenna when the reflected portion of the radio wave is received.<sup>41</sup>

Limitations in radar services prevent ATC controllers from issuing traffic advisories to aircraft that may or may not be under their control. Radio waves used in radar travel in a continuous straight line of radar that can be reflected off of objects to determine size and know distance. Radar waves can be bent, reflected, or screened by atmospheric conditions, like clouds or rain, and mountainous terrain, thus causing inaccurate readings on ATC radar screens. Additionally, the amount of reflective surface on an aircraft can affect the reliability of the radar return. Small UAS's reflective surface is too small to provide a reliable radar return making it extremely difficult to see on radar.

The use of radar beacons helps fill voids when a UAS experiences lost radar signature if an on-board transponder isn't working properly. All air route traffic control centers' (ARTCC) radars in the United States and many airport surveillance radars have the capability to interrogate Mode C transponder altitude information. However, there is a number of smaller airports that use surveillance radars but do not have Mode C display capability. Therefore, altitude information must be obtained from the pilot.<sup>42</sup>

Each person operating an aircraft in the airspace overlying the waters between 3 and 12 nautical miles from the coast of the United States must comply with Code of Federal Regulations (CFR) 14, Part 91.1 *General Operating and Flight Rules*. As a minimum, aircraft are required to have an operational coded radar beacon transponder having either Mode 3/A 4096 code capability or Mode S capability. Transponders

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<sup>41</sup> FAA. "Aeronautical Information Manual (AIM)," Section 5, 4-5-1.

<sup>42</sup> Ibid., (e).

provide code specific interrogations to Airport Traffic Control and provide altitude and directional information.<sup>43</sup>

This poses a very difficult challenge for ATC. ATC's ability to advise a pilot of their aircraft's proximity to another aircraft is limited if the UAS cannot be observed on radar. To bridge the gap with inconsistencies with radar, the FAA is in the process of fully fielding NextGen.

The Next Generation Air Transportation System (NextGen) is the Federal Aviation Administration's plan to modernize the National Airspace System through 2025. Through NextGen, the FAA is addressing the impact of air traffic growth by increasing NAS capacity and efficiency while simultaneously improving safety, reducing environmental impacts, and increasing user access to the NAS. To achieve its NextGen goals, the FAA is implementing new Performance-Based Navigation (PBN) routes and procedures that leverage emerging technologies and aircraft navigation capabilities.<sup>44</sup>

UAS integration activities need to include NextGen technology not only to ensure compatibility and ease of access in the future NAS, but also to capitalize on the performance and safety benefits of NextGen technology. To ensure long-term integration into the NAS, UAS need to be included in all appropriate aspects of NextGen planning.

### **Frequency and Bandwidth**

UAS rely on communication signals in the form of bi-directional frequencies to enable flight commands from ground control stations. These communications signals use

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<sup>43</sup> ATC Transponder and Altitude Reporting Equipment and Use, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 215(b) (2011).

<sup>44</sup> Federal Aviation Administration. "Fact Sheet: NextGen Goal - Performance Based Navigation." [http://www.faa.gov/news/fact\\_sheets/news\\_story.cfm?newsId=8768](http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=8768), (accessed January 15, 2011).



electromagnetic radiation in the form of invisible waves of energy to transmit data. The rate per second at which these waves of energy cycle is the signal's frequency. Changes in the length of the wave across the spectrum of frequency, from short to long, causes a band of frequencies. Each band of frequency has a unique characteristic as it travels through the atmosphere. The range of frequencies occupied by a given wave or the amount of data capable of transmission in a given amount of time is referred to as bandwidth.

The U.S. and international community have divided the frequency spectrum into sections defined by type (i.e., radio navigation), user (government or nongovernment), and region of the world.<sup>45</sup> Because the frequency spectrum is a finite resource, competition internal to all sections has created a market to buy and sell bandwidth. What remains becomes congested and difficult to deconflict among systems operating within the frequency spectrum. Acquiring sufficient frequency bandwidth to support UAS operations continues to be challenging.

The DoD and FAA are addressing the challenges of radio frequency allocation for UAS operations, but solving this challenge may not be completed for several years.<sup>46</sup> The International Telecommunication Union allocates radio frequency spectrum and to obtain spectrum allocation for UAS, the FAA must coordinate with the Department of Commerce (DoC) and Federal Communications Commission (FCC). Both the DoC and the FCC will meet in spring 2011 to discuss implementation and management of spectrum allocation. At this meeting, federal and non-federal use of the frequency

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<sup>45</sup> U.S. Department of Defense, *FY2009-2034 Unmanned Systems Integrated Roadmap*, C-17.

<sup>46</sup> *Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential uses within the National Airspace System: Report to Congressional Requesters*. GAO 08-511. (Washington, D.C.: U.S. Govt. Accountability Office, 2008), 31.

spectrum must be allocated to balance requirement and support safe operations. This will become increasingly difficult as military units return from deployment and UAS gain unrestricted access to the NAS.

### **Operational Challenges**

Current operational rules for airspace and aircraft are based on the existing NAS safety architecture of dependability standards, system predictability, real-time response capabilities, and safety to the public in the air and on the ground. It will be necessary to develop appropriate and specific UAS operational procedures that address UAS unique behavior and responses (e.g., interoperability, compliance with air traffic operations and lost-link procedures). Operating procedures need updating so that UAS perform in a predictable manner, thereby allowing missions to be accomplished while maintaining the safety of the NAS. To be effective, these operating procedures must be understood by the pilot and air traffic control.<sup>47</sup>

### **Interoperability**

Recent success with unmanned aerial systems in combat influenced Congress to pass the FY 2007 John Warner National Defense Authorization Act. The Act requires the DoD to establish several policies. First, DoD will identify a preference for unmanned systems when acquiring new UAS. Second, DoD will manage joint service development and acquisition of UAS and components. Third, DoD must ensure interoperability of UAS by transitioning service specific systems to joint systems. Fourth, DoD must establish an organizational structure for management of future UAS. Fifth, DoD must

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<sup>47</sup> U.S. Department of Defense, *Access to National Airspace for Unmanned Aircraft Systems*, 20.

manage all budgets and development of UAS. Finally, DoD must develop a plan to assess progress toward meeting goals established in Section 220 of the National Defense Authorization Act of FY2001, where one-third of the operational joint deep strike aircraft will be unmanned.<sup>48</sup> The John Warner National Defense Authorization Act is a monumental step in the right direction for the DoD to ensure future UAS interoperability.

Interoperability is defined in Joint Publication 1-02 as “the ability to operate in synergy in the execution of assigned tasks. When executed correctly, it can become a force multiplier and can simplify logistics.”<sup>49</sup> Additionally, Department of Defense Directive (DoDD) 5000.1 establishes the requirements for UAS to demonstrate in order to meet a number of levels of interoperability<sup>50</sup>

Interoperability is “achieved by buying common parts, components, and software under a common system.”<sup>51</sup> Traditionally, unmanned aircraft operations have been impeded by their lack of interoperability. Operations in Afghanistan and Iraq have identified the lack of standards across the DoD and internal within the services have resulted in UAS that are not interoperable. The reason for the lack of interoperability is the result of each service pursuing their own UAS programs but can also be observed within the services themselves. Two of the best examples are the Army’s Shadow, and Hunter, UAS. Army forces operate both systems and associated ground equipment but have discovered the Shadow’s sensor and communications systems are unable to transmit

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<sup>48</sup> *John Warner National Defense Authorization Act*, Public Law 109-364, Title I, Subtitle D, Sec. 141 and Title IX, Subtitle E, Sec. 941 (October 2006). <http://www.csg.org/knowledgecenter/docs/PL109-364.pdf> (accessed January 20, 2011).

<sup>49</sup> U.S. Joint Chiefs of Staff. *DoD Dictionary of Military and Associated Terms*, Joint Publication 1-02. (Washington, DC: Joint Chiefs of Staff, November 8, 2010), 186.

<sup>50</sup> Department of Defense Directive 5000.1. *The Defense Acquisition System* (Ft. Belvoir: Defense Technical Information Center, May 2003), Encl. 1, para. E1.10.

<sup>51</sup> U.S. Department of Defense, *FY2009-2034 Unmanned Systems Integrated Roadmap*, 178.

to a Hunter ground station. Similarly, the Hunter has the same shortcomings when trying to transmit to the Shadow's ground system.<sup>52</sup>

Since July 2009, DoD has made several key investment decisions regarding unmanned aircraft systems that are contained in the 2010 Quadrennial Defense Review, DoD's fiscal year 2011 budget request, and DoD's Aircraft Investment Plan (2011-2040). Although the decision outlined in each one of these documents emphasis developing greater capabilities and increasing overall numbers of UAS, they do not appear to focus on 'increasing collaboration or commonality among unmanned aircraft programs.'<sup>53</sup>

According to recent GAO report in March 2010 on Defense Acquisitions, it was reported that some unmanned aircraft acquisition programs leveraged resources and gained efficiencies in their programs. For example, the Army and Marine Corps achieved full commonality in the Shadow UAS program.<sup>54</sup> The Marine Corps determined the Army Shadow UAS could replace their aging fleet while still meeting their requirements for intelligence, surveillance, reconnaissance, and target acquisition. Effectively, the Marine Corps avoided additional costs in developing a new system and benefited from support activities because their components are interchangeable with the Army.

In some cases, the services had collaborated to identify common configuration, performance and support requirements, but ultimately failed to maximize efficiencies.

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<sup>52</sup> *Unmanned Aircraft Systems: DOD Needs to More Effectively Promote Interoperability and Improve Performance Assessments: Report to the Subcommittee on Tactical Air and Land Forces, Committee on Armed Services, House of Representatives* (Washington, D.C.: U.S. Government Accountability Office, 2005), 10.

<sup>53</sup> Michael Sullivan, *Defense Acquisitions DOD Could Achieve Greater Commonality and Efficiencies Among Unmanned Aircraft Systems* (Washington, DC: Government Accountability Office, ), 3.

<sup>54</sup> *Ibid.*, 7.

For example, the Army and Navy had different data link requirements for their variants of the Fire Scout UAS, mainly, because of the Army's requirement for its variant to operate with the Future Combat Systems network. According to the contractor, the Army system could have been equipped with the same data link as the Navy Fire Scout, as well as several other systems the Army already fielded, resulting in a the Fire Scout being put into service sooner.<sup>55</sup>

To meet current policy established by the John Warner National Defense Authorization Act, DoD's unmanned systems will need to demonstrate interoperability on a number of different levels. First, DoD must exhibit UAS interoperability within and outside service components. Second, DoD must exhibit UAS interoperability while conducting operations with coalition and allied militaries. Third, interoperability must be achieved with other governmental agencies like Customs and Border Patrol or Homeland Defense. Finally and most important, interoperability must be demonstrated with commercial or civilian aircraft operating within the NAS to ensure full integration.

### **Air Traffic Operations**

Air traffic regulations are developed to ensure that aircraft operating within the NAS are flown safely and do not pose a risk to people or property in the air and on the ground. The FAA's air traffic services provide day-to-day flight support to people operating within the NAS. Within the NAS, there are six classes of defined airspace (see Appendix 1, Classes of Airspace). Specific air traffic procedures and requirements for each class of airspace are outlined in FAA regulations per Title 14 CFR. To successfully fly within the NAS, UAS must meet these requirements.

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<sup>55</sup> Sullivan, 7.

Analysis of FAA and DoD UAS categories reveals gaps in regulatory infrastructure and terminology. The DoD's intention to integrate UAS in the NAS is impeded by their ability to define UAS categories in-line with current FAA regulations. The difference in DoD and FAA UAS categories makes it difficult to align operating requirements. First, the FAA does not specifically define categories of UAS but instead, places all aircraft (manned and unmanned) into three categories: certified, nonstandard/LSA, and radio controlled (RC). The DoD defines UAS into three categories: Categories I-III. To complicate requirements, the Joint UAS Center of Excellence defines UAS into five groups (see table 2: Joint UAS Categories, page 22). Review of the DoD's *FY 2009-2034 Unmanned Systems Integrate Roadmap* reveals their recommendation to align the FAA's categories with the three DoD UAS categories I-III.

First, Cat. III UAS, like the Global Hawk, that routinely operate outside of restricted or in international airspace must conform to certified manned aircraft requirements by waiver to 14 CFR 91.<sup>56</sup> Therefore, it is recommended that specific modifications to 14 CFR 91 occur to ensure Cat. III UAS are treated similarly to manned aircraft operating within the NAS.

Second, the FAA has approved a Light Sport Aircraft (LSA) category in the non-standard aircraft class. The LSA category is similar to the military's RQ-7 Shadow UAS and does not require either airworthiness or pilot certification per 14 CFR 103.<sup>57</sup> LSA aircraft achieve the same level of safety, as certified aircraft, but require a lower level of

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<sup>56</sup> General Operating and Flight Rules, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 1-9 (2011).

<sup>57</sup> Ultralight Vehicles, *U.S. Code of Federal Regulations*, 14, Part 103, sec. 1-7 (2011).

reliability to operate within the NAS. Therefore, it is recommended that Cat II UAS be placed in the FAA non-standard aircraft/LSA category to facilitate access into the NAS.

Finally, the FAA has not established any regulatory restrictions to radio controlled (RC) aircraft operating below 1200 feet above ground level (AGL). The only document that addresses RC airplane operations is the FAA's Advisory Circular (AC) 91-57 which is advisory only. The DoD currently operates UAS in the same specifications as the RC model aircraft (i.e., the Raven and Dragon Eye UAS). Therefore, it is recommended that Cat I UAS be placed within the RC model aircraft category.

Although the DoD's recommendation to align UAS categories provides clarity and linkage to FAA regulatory requirements, it falls short with limiting confusion with Joint UAS categories. To limit confusion to regulatory requirements, it is recommended that the FAA define specific categories for UAS within Title 14 CFR and consider adoption of the Joint UAS categories (see table 2) as a more complete classification system.

### **Lost-Link Procedures**

Unmanned aircraft must be provided a predictable and reliable automatic recovery system in the event of lost communications link between the operator and the aircraft. It is highly desirable for all UAS to have systems of redundancies and independent functionality to ensure the overall safety and predictability of the system.

UAS communications and control links are vulnerable to radio interference. Intentional or unintentional radio interference can result in loss of aircraft control and

possible catastrophic accident. Additionally, ground control systems may require physical security protection to guard against potential hostile takeover.<sup>58</sup>

It is extremely important to protect communications links to UAS to ensure the safety of other aircraft and avoid potential hazard to people and properties on the ground. Unmanned aircraft lack dedicated protected frequencies, unlike manned aircraft. The unprotected frequencies are vulnerable, like wireless frequencies on a cell phone, to unintentional and intentional interference. Interruption of radio frequency can sever the only means of control for a UAS and this remains a key concern of the FAA.

The UAS has a backup system in case of potential interruption of frequencies. These back systems are called lost-linked procedures and are pre-programmed maneuvers. If the command and control link is interrupted while the UAS is in flight, the pre-programmed maneuver will automatically take over flight and direct the UA to land. Lost-link procedures provide a means for safe return to the ground if operators cannot reestablish the communications link before the UAS runs out of fuel. However, these procedures are not standardized across all types of UAS and, therefore, remain unpredictable to air traffic controllers.

Predictability of UAS performance under a lost-link scenario is particularly important for air traffic controllers who have responsibility for ensuring safe separation of aircraft in their airspace.<sup>59</sup> These procedures need to be assessed for each UAS so that all stakeholders, including ATC, know what defines a lost-link event and agree to a set of procedures when a lost-link event occurs.

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<sup>58</sup> GAO 08-511, 17.

<sup>59</sup> Ibid., 18.



## **CHAPTER 5**

### **RECOMMENDATIONS**

It is clear that successful integration of unmanned and manned aircraft within the National Airspace System (NAS) will be difficult and require coordination from many DoD and civilian agencies. Successful integration of UAS into the NAS requires a thorough analysis of requirements to identify gaps in safety standards, regulations governing flight within the NAS, technological requirements and operational challenges.

#### **Safety Standards**

The FAA's main concern about integrating manned and unmanned aircraft within the NAS is safety. UAS must be able to meet and exceed safety standards while operating seamlessly with manned aircraft in the NAS. The approach to safety risk management must start with establishing a reliable target level of safety (TLS) baseline for UAS operating within the NAS. Two potential solutions exist that can help with establishing a TLS baseline. First, it is recommended that modeling and simulations be used to replicate UAS and manned flight scenarios in the NAS. These scenarios could apply to every known or potential issue that could occur with flight in the NAS. Data could be obtained without any risk to personnel or property. Second, once a TLS baseline has been established through modeling and simulations, the FAA should seek to conduct limited manned and unmanned flights in non-segregated airspace. This would further validate data and expand the TLS baseline. Establishing a reliable TLS baseline will help direct analysis for aircraft separation, collision avoidance, coordination of information and contingency planning.

Unmanned aircraft system reliability has improved considerably over the past five years of operations in Afghanistan, Iraq, and the United States. UAS reliability must continue to meet and exceed manned aircraft reliability standards to dispel common misperceptions of performance and safety. Aircraft design and maintenance procedures must focus on continuing to improve on aircraft reliability.

The FAA should establish one airworthiness standard for UAS and not differentiate between public and civilian aircraft. If the DoD is to successfully integrate UAS within the NAS they should do so under one standard. This would ensure the FAA maintains their charter by law to keep our airways safe.

### **Updating Regulations**

The FAA has sole authority over the safe and efficient use of the NAS. The FAA's policies and air traffic regulations are meant to ensure the safety of the citizens of the United States while ensuring safe aircraft operations within the NAS. The FAA must define and update terms associated with current and future UAS operations within the NAS. Title 14 CFR should specifically address UAS operations and standards in the NAS.

Two options are recommended for modification to Title 14 CFR. Option one; amend every regulation and statute to resolve any ambiguity as to applicability to UAS design, manufacture, and operation. Option two; create an entirely new subpart of Title 14 CFR that specifically outlines UAS operations and requirements within the NAS.

The current Memorandum of Agreement (MOA) with between the FAA and DoD must be updated to include other airspace access. Additionally, Certificate of Authorizations (COA) procedures are cumbersome and not responsive. The FAA must

address current backlog of applications, long approval times, prioritization, and processing times. The FAA is not prepared for the large influx of UAS from military deployments, and staffs are undermanned to process request. The COA process must be streamlined through implementation of file-to-fly procedures. Ultimately, the goal is to integrate UAS into the NAS without the use of a COA. This will be a long process as future technological advancements will allow aircraft to meet equipage requirements.

### **Technology Integration**

To minimize the risk of midair collisions, UAS operators must be able to detect and track air traffic to a level of safety equal to or better than that required by current regulatory guidance. Most manned aircraft, which operate under VFR and lack collision avoidance systems, rely on the pilot's eyesight and radio contact with air traffic controllers to track approaching airborne vehicles. The DoD and FAA must implement the ground and the air based sense-and-avoid systems (GBSAA and the ABSAA) to compliment the Mode C transponders for UAS operations. Combining all three systems will provide ATC situational awareness of both transponder equipped and non-equipped UAS. Implementation of these systems will help gain valuable data for analyzing and improving manned and unmanned integration.

Equipping UAS with TCAS transponders to communicate with other transponder-equipped aircraft reduces the possibility of midair collisions but does not reduce possible collisions with non-equipped aircraft. Aircraft without TCAS transponders continue to pose a significant risk when flying under visual flight rules. For this reason, UAS operators must be equipped with a sense and avoid system that can locate and track both TCAS transponder equipped aircraft and non-equipped aircraft at sufficient range to

maintain safe separation distances.

Although the FAA is pursuing dedicated radio frequency spectrum to address UAS communications and control vulnerabilities, this is not an easy challenge to solve. Frequency and bandwidth availability is a finite resource. It is recommended that the FAA and DoD work together to find harmonization between frequency needs and performance requirements. Reallocation of frequency distribution will need to be considered to ensure equity between the DoD and civilian counterparts.

### **Operational Improvements**

Current operational rules for airspace and aircraft are based on the existing NAS safety architecture. In October 2010, the Department of Defense conducted an assessment of UAS needs for accessing the NAS and with the Joint UAS Center of Excellence (JUAS CoE) consolidated these needs into six different access groups organized around phases of flight.

The six access groups are defined as: Line-of-Sight, Terminal, Military Operations Areas, Lateral Transition, Vertical Transit, and Dynamic. Current DoD COAs that fall within these groups total 57 for year 2010. The DoD has forecasted the military's access requirements will more than double by 2015 to 137.<sup>1</sup>

A large percentage of DoD UAS flights require visual line-of-sight operations. The majority of line-of-sight operations are conducted in Class G airspace per rules outlined in the 2007 DoD-FAA MOA. Under this agreement, military services do not require a COA to operate UAS line-of-sight but must notify the FAA of intentions.

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<sup>1</sup> U.S. Department of Defense, *Access to National Airspace for Unmanned Aircraft Systems* (Washington, DC: 2010), Attachment 2, Site Transition Plan, 3. [www.acq.osd.mil/psa/docs/report-to-congress-ana-for-uas.pdf](http://www.acq.osd.mil/psa/docs/report-to-congress-ana-for-uas.pdf) (accessed March 15, 2011).

The FAA is considering recommendations to develop a special federal aviation regulation (SFAR) to facilitate small UAS access to the NAS without requiring a COA. If the SFAR passes then access for line-of-sight UAS will dramatically improve. If the SFAR does not pass, the proliferation of UAS into the NAS will result in a rapid increase of COAs.

Terminal area operations involve ground and flight operations within Class D and E airspace. The DoD has a need to operate within the terminal area that facilitates engine start and run-up, taxiing, departure and approaches, and pattern flight. To successfully operate within the terminal area, manned and unmanned flight must share airspace. New and emerging technologies previous discussed in Chapter 4 are being evaluated by the DoD and FAA to ensure safe aircraft operations

Military Operations Areas (MOAs) provide the opportunity for DoD UAS to operate freely within a designated volume of airspace without potential threat to non-participating aircraft. UAS operational and maneuvering capabilities can be taken full advantage of with reduced risk to non-participating aircraft. Safe operations within MOAs can be ensured through established procedures with the FAA.

Over 500 MOAs exist in the NAS and provide restricted access to over 43 states and a half million square miles of operating space.<sup>2</sup> Using existing MOAs would streamline access and reduce the need for FAA approval.

Lateral transit operations are required for DoD to transition from one controlled airspace to another. Transition occurs between terminal areas, restricted areas, or other controlled airspace for deployment or ferrying operations. Transitioning areas represent a

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<sup>2</sup> U.S. Department of Defense, *Access to National Airspace for Unmanned Aircraft Systems*, Figure 4, 83.

horizontal tunnel to transit Class E to restricted airspace. Though the lateral transit area may exist at any altitude, the primary transition would occur in Class E airspace.

Establishing approved procedures for lateral transition, implemented with enabling technologies like GBSAA, can ensure manned and unmanned separation.

Vertical transit areas are vital for UAS to gain access to Class A airspace. UAS originating flight from Class E or restricted airspace will use vertical transition via terminal areas to gain access to Class A airspace. Emerging radar technologies and defined ATC coordination procedures will provide vertical transition flight separation similar to lateral transit procedures.

Dynamic Operations would allow immediate access to the NAS similar to today's manned flights. Dynamic operation would provide COCOM Commanders the flexibility to meet rapidly changing contingency operations by integrating UAS with manned aircraft throughout the entire depth of the NAS. Operations would require autonomous self-separation and collision avoidance through the use of ABSAA and NEXTGEN systems. Additionally, dynamic operations would allow access to the NAS through FAA approved flight plans. Currently, the Air Force Global Hawk and the Navy Broad Area Maritime Surveillance (BAMS) programs are the only systems that are equipped in accordance with Title 14 CFR to fly this dynamic profile.

Through development and refinement of policies, procedures, and technological advances in radar, each access group will provide potential access points to the NAS. Either as a stand-alone access group or integrated together, all possible airspace requirements of the DoD could be met through the implementation of these six access groups.

## **CONCLUSION**

This study has shown that the integration of UAS into the NAS will continue to be challenging for the Department of Defense and the Federal Aviation Administration, and will require our government's emphasis to resolve. Both organizations agree it is important and necessary for expansion of UAS operations within the NAS. Providing unrestricted access to the NAS is crucial to maintain operational control of UAS flights, maintain our military's operational and tactical level readiness, and reduce overall risk to civilian life.

The increase in the number of UAS flights into an already busy NAS presents significant safety and resource challenges. As both military and civilian UAS development expands, it is imperative that the FAA and DoD work together to streamline procedures and field new technology to safely integrate UAS within the NAS. The relative size and design of many UAS make them difficult to recognize in flight. Adequate sense and avoid technology is years away. Combining current ATC systems and restructuring airspace procedures will meet immediate demands for increased UAS access to the NAS.

There are many challenges to overcome to arrive at a desired end state of full access to the NAS for UAS. Integration with manned aircraft, achieving transparency within air traffic management, and maintaining a safety record equal to or better than manned aircraft are essential to success. Decisions being made about UAS airworthiness and operational requirements must fully address safety implications of UAS flying in the same airspace as manned aircraft, and perhaps more importantly, aircraft with passengers.

History has shown that following a period of transition from wartime operations,

UAS advancements become second priority to budgetary cuts and restructuring. To overcome the challenges of integrating manned and unmanned aircraft into the same airspace before history has the opportunity to repeat itself, our government's emphasis on resolution is required.



## APPENDIX A

### CLASSES OF AIRSPACE

This appendix provides a quick reference for regulatory and non-regulatory airspace defined in Title 14 of the Code of Federal Regulations. Controlled, uncontrolled, and special use airspace is outlined in tables 8 and 9. Listed in table 8 are five classes of controlled airspace (A-E) and one class of uncontrolled airspace (G) in the NAS. Table 9 outlines special use airspace normally reserved for military operations and where the abundance of UAS operations are conducted.

Table 7: Classifications of Airspace

Airspace	Altitude	Description / Requirements
Class A	18,000 – 60,000 feet MSL (FL 180 – FL600)	This airspace extends within 12 nautical miles of the coast of the 48 contiguous States and Alaska. To operate within Class A airspace requires aircraft to operate under instrument flight rules (IFR), have an operational radio navigational signal, and remain under control of air traffic control (ATC) at all times. Class A airspace is used primarily by commercial civilian flights, medium altitude long endurance (MALE) UAS, or Groups 3-5 Joint UAS categories. Class A airspace is primarily used for aircraft to transition from and to other airspace classifications. <sup>1</sup>
Class B	Surface – 10,000 feet MSL	Class B airspace is controlled airspace that surrounds some of our nations busiest airports and is used primarily for aircraft arrivals and departures. As a minimum, Class B airspace will include two inverted layers of airspace defined by diameter and altitude. When viewed from the side, the airspace will resemble an upside down wedding cake. To successfully operate within Class B airspace an aircraft must first obtain prior approval from ATC. Once approval is obtained the aircraft must establish two-way radio communications with ATC and have an operational Mode C capable transponder to provide ATC with the aircraft's location. <sup>2</sup>
Class C	Surface – 4,000 feet MSL (5NM circle) and 1,200 – 4,000 feet	To successfully operate within Class C airspace, aircraft must meet the same operational requirements as Class B airspace. Aircraft separation of aircraft on visual and instrument flight plans is provided by a radar approach control. <sup>3</sup>

<sup>1</sup> Operations in Class A Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 135 (2011).

<sup>2</sup> Operations in Class B Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 131 (2011).

<sup>3</sup> Operations in Class C Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 130 (2011)

	MSL (10NM circle)	
Class D	Surface – 2,500 feet MSL	Class D airspace is airspace around an airport with an operation control tower. To successfully operate within Class D airspace, an aircraft must maintain two-way communications with air traffic control services for that specific airport. Separation services are not provided in Class D airspace and pilots must provide their own visual separation. <sup>4</sup>
Class E	Surface of an airport but generally starts at 1200 feet above ground level (AGL) or 14,500 MSL until it meets a higher-level class of airspace. Class E airspace also starts at 60,000 feet and above.	Most airspace within the NAS is Class E. There are no radar or clearance procedures to successfully operate within Class E airspace but an aircraft must maintain visual clearance of cloud cover defined in the Airman’s Information Manual (AIM) 3-1-4. There are two requirements for maintaining separation from clouds based on whether an aircraft is operating below or above 10,000 feet MSL. Operating below 10,000 feet MSL requires at least 3 miles visibility from any cloud obscuration. Additionally, the aircraft must fly an altitude at least 500 feet above, 1,000 feet above, and 2,000 feet laterally from clouds during the flight. To operate an aircraft in Class E airspace above 10,000 feet MSL requires at least 5 miles visibility from any cloud obscuration. Additionally, minimum aircraft flight altitudes increase to 1,000 feet above or below, and 1 mile laterally from clouds. <sup>5</sup>
Class G	Surface – 14,449 feet MSL but generally below 1,200 feet AGL	Class G airspace is also known as “uncontrolled airspace”. Class G airspace is considered uncontrolled because ATC does not control aircraft within this airspace but will provide advisories upon request. Requirements to successfully operate within Class G airspace are the same as Class E airspace. Radio communication is not required to operate under visual or instrumental flight rules while in Class G airspace. <sup>6</sup>

Source: Created by Author using information obtain from *U.S. Code of Federal Regulations*, 14, Part 91.

Special use airspace, outlined in table 9, is divided into six separate types:

prohibited, restrictive, warning, alert, military operations area, and controlled firing area.

DoD UAS operations are currently limited primarily to restrictive and warning areas.

<sup>4</sup> Operations in Class D Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec 129 (2011).

<sup>5</sup> Operating on or in the Vicinity of an Airport in Class E Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec. 127 (2011).

<sup>6</sup> Operating on or in the Vicinity of an Airport in Class G Airspace, *U.S. Code of Federal Regulations*, 14, Part 91, sec 126 (2011).

Table 8: Special Use Airspace Classifications

<b>Type</b>	<b>Description</b>
Prohibited	Areas where, for reasons of national security, the flight of an aircraft is not permitted are designated as prohibited areas. Prohibited areas are depicted on aeronautical charts. For example, a prohibited area (P-56) exists over the White House and U.S. Capitol.
Restricted	In certain areas, the flight of aircraft, while not wholly prohibited is subject to restrictions. These designated often have invisible hazards to aircraft, such as artillery firing, aerial gunnery, or guided missiles. Aircraft operations in these areas are prohibited during times when it is “active.”
Warning	A warning area contains many of the same hazards as a restricted area, but because it occurs outside of U.S. airspace, aircraft operations cannot be legally restricted within the area. Warning areas are typically established over international waters along the coastline of the United States.
Alert	Alert areas are shown on aeronautical charts to provide information of unusual types of aerial activities such as parachute jumping areas or high concentrations of student pilot training.
Military Operations Area (MOA)	Military operations areas (MOA) are blocks of airspace in which military training and other military maneuvers are conducted. MOA’s have specified floors and ceilings for containing military activities. VFR aircraft are not restricted from flying through MOAs while they are in operation, but are encouraged to remain outside of the area.
Controlled Firing Area (CFA)	CFAs contain activities that could be hazardous to nonparticipating aircraft. CFA are not charted so they do not require nonparticipating aircraft to change their flight path. Activities are suspended immediately when non-participating aircraft approach the area.

Source: Created by Author using information from FAA, *Aeronautical Information Manual*, Section 4 and Order JO 7400.8S, Special Use Airspace.

## APPENDIX B

### LEVELS OF AIRWORTHINESS

This appendix provides a graphic representation of approved levels of airworthiness the DoD uses to certify UAS. The FAA does not require government owned or operated UAS to be certified airworthy in accordance with FAA standards for civilian aircraft. All military UAS go through an established airworthiness certification process. Unity of effort is achieved by all services through a tri-service MOA that outlines all regulatory requirements.

Figure 2: Levels of Airworthiness

Vehicle Size	General Guidance		Airspace		
	Max Wt (lbs)	Max Speed (kts)	International & National	Active Restricted & Combat Zones	Expendable UA in Active Restricted
Med/Large	>1320	>200	1	2	3
Light	Up to 1320	200	1	2	3
Small/Mini/Micro	Up to 55	120	COA Process	3	3

Source: *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army* (Fort Rucker, AL: US Army Unmanned Aircraft Systems Center of Excellence, 2010), Figure E4, 110.

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